NOAA Technical Memorandum NWS SR-184

WEATHER SUPPORT FOR THE

XXVI OLYMPIAD

Principal Authors

Lans P. Rothfusz
National Weather Service Forecast Office
Tulsa, Oklahoma

Melvin R. McLaughlin
National Weather Service Southern Region Headquarters
Fort Worth, Texas

National Weather Service
Southern Region
Fort Worth, TX

March 1997

UNITED STATES
EPARTMENT OF COMMERCE
/illiam M. Daley, Secretary

National Oceanic and Atmospheric Administration
James Baker
Under Secretary and Administrator

National Weather Service
Elbert W. Friday
Assistant Administrator

Contents

Weather Support for the XXVI Olympiad

Prologue

'Something Wonderful Happened In Georgia'

There are places and events where exhilaration takes hold, vision is expanded, and behavior is altered. In the vernacular, such manifestations are called mountaintop experiences. For the majority of us involved in weather support project for the 1996 Centennial Olympic Games, it was a mountaintop experience.

From the outset, those involved with the project saw a golden opportunity to make something good happen, and they seized that opportunity, permitted themselves to dream, and then with single-mindedness, dedication, and drive, worked together to make it happen. In the early stages of the project, critical climatological information necessary for venue selections was given to the Olympic Organizing Committee. Later, we worked together to design, create, test, and place into operation, in the remarkably short time span of two years, a state-of-the-art weather support system. Olympic Weather Support forecasters subsequently used that system to provide a level of weather forecast and warning services for the 1996 Olympic Games which was unprecedented in the annals of the National Weather Service. The Chief Operating Officer of the Atlanta Committee for the Olympic Games stated:

> "The National Weather Service worked closely with ACOG in the years preceding the Games to put in place the most technologically advanced weather monitoring and advanced warning system in history. The Olympic Weather Forecast Center in Peachtree City proved to be one of the most valuable assets to ACOG's operational efforts. Your system insured the overall health and welfare of the Olympic athletes, officials, and spectators....Thanks to your support and dedication, the Games of the XXVI Olympiad were truly the best in Olympic history."

While that is indeed a glowing accolade, a question posed by an Associated Press reporter after the Games was even more telling. He quipped, "I guess weather didn't affect the Games, huh?" This could not have been further off the mark. Scores of times, events were rescheduled because of weather, spectators and athletes were moved to shelter because of weather threats, and steps were taken to mitigate the effect of excessive heat. So why did this reporter (and most of the population) not notice? They did not notice because Olympic officials were able to take steps to minimize these weather-related impacts as a result of the excellence of the advanced weather warning and forecast services provided to them by the Olympic Weather Support Office and the Olympic Marine Weather Support Office. But possibly the truest measure of the success of the Olympic Weather Support Project is that not a single person was killed or even significantly harmed by weather during the XXVI Olympiad.

This project successfully pushed the boundaries of science, service, skill, and technology, and in so doing provided direct benefit to the Olympic Games, enabled the United States to showcase its advanced technology in the international arena, and pointed the way to what could happen in the future of operational meteorology. In addition, it served to demonstrate that when skilled and innovative people choose to work together for the common good, and when those who sit in the seats of power willingly and deliberately choose to provide those people with the support and flexibility needed to do so, grand and wonderful things *will* happen. That is what made the Olympic Weather Support Project a mountaintop experience, and that is why *something wonderful happened in Georgia.*

Mac McLaughlin

Weather Support for the XXVI Olympiad

Lans P. Rothfusz[1], Melvin R. McLaughlin[2], Stephen K. Rinard[3], Tom Black[4], Luis Cano[4], Geoff DiMego[4], JT Johnson[5], Clark Safford[6], John Snook[7], Sondra Young[4]

[1]NWS Forecast Office, Tulsa, OK
[2]NWS Southern Region Headquarters, Ft. Worth, TX
[3]NWS Office, Lake Charles, LA
[4]National Centers for Environmental Prediction, Camp Springs, MD
[5]National Severe Storms Laboratory, Norman, OK
[6]NWS Forecast Office, Peachtree City, GA
[7]Forecast Systems Laboratory, Boulder, CO

1. Introduction

Since the resumption of the Olympic Games in 1896 (referred to as the Modern Olympic Games), the host country, operating either through its National Olympic Committee and/or the Organizing Committee for the Olympic Games has been given the responsibility for all the physical support associated with hosting the Games. Specifically, the Olympic Charter of the International Olympic Committee (IOC)[1] states:

> "The organization of the Olympic Games shall be entrusted by the IOC to the National Olympic Committee (NOC) of the country in which the chosen city is situated. Such NOC may, and if it does not possess legal personality shall, delegate the duties with which it has been entrusted to an Organizing Committee formed for the purpose which shall thereafter communicate directly with the IOC....
>
> The object of the NOCs (and OCOGs), in accordance with the fundamental principles contained in these Rules, shall be to ensure the development and safeguarding of the Olympic Movement and sport. NOCs (and OCOGs) shall be the sole authorities responsible for the representation of their respective countries at the Olympic Games...NOCs (and OCOGs) must be autonomous and must resist all pressures of any kind whatsoever, whether of a political, religious or economic nature. In pursuing their objectives, NOCs (and OCOGs) may co-operate with private or government organizations. However, they must never associate themselves with any undertaking which would be in conflict with the principles of the Olympic Movement and with the Rules of the IOC."

The provision of meteorological support for the quadrennial celebration of the Olympic Games is a part of the physical support function expected of the host country in accordance with rules and regulations specified in the Olympic Charter of the International Olympic Committee.

---

[1] The IOC was created by the Congress of Paris of 23rd June 1894, which entrusted to the IOC the control and development of the modern Olympic Games. The IOC is a body corporate under international law having juridical status and perpetual succession.

Traditionally, the provision of such meteorological support has been a responsibility assigned to the national meteorological service of the host country. For example, The Australian Bureau of Meteorology provided support for the 1956 Games in Melbourne; the Japanese Meteorological Service provided support to the 1964 Games in Tokyo; the Meteorological Service of Mexico provided support for the 1968 Games in Mexico City; the Atmospheric Environment Service of Canada provided support to the 1976 Games in Montreal; the United States National Weather Service provided support to the 1984 Games in Los Angeles, and the Spanish Meteorological Service provided support to the 1992 Games in Barcelona.

The Atlanta Organizing Committee for the Olympic Games first contacted the Atlanta National Weather Service Office in 1989, when the city was preparing its bid for the 1996 Games. The Committee wanted climatological data incorporated in the bid package, and requested the data from the NWS forecast office in Atlanta.

In September 1990, the International Olympic Committee chose Atlanta, Georgia, as the host city for the 1996 Centennial Olympic Games. Thereafter, the Atlanta Committee for the Olympic Games (ACOG), formerly known as the Atlanta Organizing Committee for the Olympic Games, began planning for hosting the Games.

At the outset, the Committee recognized that the weather would be a major concern, and on July 14, 1992, the ACOG, a private, non-profit corporation, acting under the auspices and authorities of the International Olympic Committee and the United States Olympic Committee, requested the National Weather Service (NWS) provide meteorological support to help ensure the safe conduct of the 1996 Games. On November 30, 1992, the NWS agreed to provide the requested weather support, and the Secretary of Commerce reaffirmed the NWS weather support role for the Games on May 12, 1993.

In providing weather support for the 1996 Olympic Games, the United States National Weather Service was acting:

- in accordance with long standing international agreements established by the International Olympic Committee;
- under sanction of the World Meteorological Organization;
- under the authority of 15 USC 313 et seq. which provides the National Weather Service the authority to provide weather warnings, to forecast the weather, and to take and disseminate meteorological observations.

2. History

Chronology of Events[2]

1989	Numerous contacts between Atlanta's Civic Leaders and WSFO Atlanta regarding the City's bid for the '96 Summer Games.
1990	Carlos Garza, Peachtree City, GA, WSFO AM/MIC works with the University of Georgia and the Olympic Organizing Committee to place mesonetwork sensors at potential venue sites.
1991	
April	The Atlanta Committee for the Olympic Games (ACOG) makes initial contact with NWS AM for Georgia, regarding weather support for the Olympics.
1992	
Jul 14	ACOG writes to Dr. Friday, Director NWS, formally requesting NWS to provide weather support for the 1996 Games.
Nov 30	Dr. Friday writes to Mr. Battle, ACOG, agreeing to provide weather support to the Games; announces the appointment of the Olympic Weather Support Project Coordinator and the formation of the Olympic Weather Support Committee (OWSC).
1993	
Feb 23-24	OWSC holds organizing meeting in Atlanta; meets with ACOG representatives, and lays initial groundwork; establishes subcommittees.
Mar 11	Justification and proposed budget request for the Olympic support effort submitted to NWSH.
Apr 6	ACOG writes to Secretary of Commerce requesting support for NWS budget request.
April 23	Ira Brenner and Steve Rinard appointed Meteorologists-in-Charge of the two Olympic Weather Support Offices.
May 12	The Secretary of Commerce writes to ACOG committing the DOC and NWS to providing required weather support services for the 1996 Games.
Aug 11-12	OWSC meets in Fort Worth. Specific action items and milestones established.
Nov 22	Interest Announcement for Forecast Teams Distributed.
1994	
Feb 8-9	OWSC meets in Boulder, CO, to consider hardware and software requirements to support warning and forecast operations.
Mar 22	NSSL representatives visit Fort Worth to brief the Olympic Weather Support Project Coordinator, Chair OWSC, MIC Olympic Weather Support Office (OWSO) and MIC Olympic Marine Weather Support Office (OMWSO) on possible NSSL participation in support effort, and demonstrate technology for accessing and using advanced techniques for utilizing WSR-88D data.

[2]Various acronyms are defined subsequently in the body of the report when they first appear.

1994 (cont)	
Apr 5	Lans Rothfusz selected as MIC of the OWSO when the former MIC departs for another assignment within the NWS.
Apr 7	OWSC meets with ACOG to discuss ACOG participation in obtaining technology support.
May 9-10	Chair, OWSC, MIC OWSO and MIC OMWSO visit NMC to evaluate National Center software and technology capabilities, and to discuss NMC offer of support for the Olympics effort.
Jun 7	Olympic Weather Support Project Coordinator briefs NWS Director Friday concerning proposals and plans for NWS weather support for the '96 Games. Dr. Friday gives approval to proceed.
Jun 21	NDBC deploys buoy off Wassaw Sound and begins data collection.
Jul 26	OSF agrees to provide support to NSSL for algorithm development in support of the Olympics.
Jul 28	Campbell Scientific units deployed at selected venue sites.
Aug 12	Procurement of additional Campbell Scientific units initiated.
Aug 15	Dr. Friday invites participation in Olympic weather support activities by the Canadian Atmospheric Environment Service and the Australian Bureau of Meteorology.
Aug 23	NWS submits request for funding support from the Administrator's Distribution Fund.
Aug 29	Procurement of workstations for OWSO and OMWSO initiated.
Aug 30	Australian Bureau of Meteorology commits forecasters to Olympic support.
Sep 1	Members and alternates of the OWSO and OMWSO forecast teams identified.
Sep 27-28	OWSC meeting in D.C. Most OWSS components decided at this meeting.
Sep 28	NOAA Comptroller rejects ADF request.
Oct 4	Canadian AES commits forecasters to Olympic support.
Nov 7	SunSparc workstation and furniture for OWSO installed.
Nov 17 - 18	Olympics support technical meeting held in Peachtree City.
Nov 17	HP 755s arrived. HP 715s arrived in early December.
1995	
Jan 8	JT Johnson reports for duty as SOO of OWSO.
Feb 17	First meeting with ACOG venue and competition managers.
Feb 22	Dr. James Baker, NOAA Under Secretary and Administrator, visits the OWSO.
Feb 28	Georgia Environmental Protection Division offers air quality data & assistance.
Mar 17	NOAA places a hold on all Olympics weather support preparations.
Apr 7	Dr. Baker meets with Dr. Friday and gives NWS clearance to resume Olympic support activities.
Apr 7	ACOG unveils weather story boards for Info'96.
Apr 25	NCEP & TDL begin discussing ways for ICWF to ingest model gridpoint data.
May 3	WDSS installed in OWSO.
May 22 - 25	Training video produced.
Jun 22	Chris Jacobson (meteorologist intern/programmer) begins working in OWSO.

1995 (cont)	
Jun 22 - 25	Limited weather support given to rowing competition at Lake Lanier.
Jun 30	Karen McPherson (IBM) makes initial contact and asks if IBM can help.
Jul 6	Clark Safford discovers and fixes vexing bug in off-the-shelf fax software.
Jul 20	First forecaster team arrived for training.
Jul 29 - Aug 20	Weather support given to Atlanta Sports Festival '95.
Sep 5 - 9	Limited weather support given to diving competition at GA Tech.
Sep 22 - 24	Limited weather support given to rowing competition at Lake Lanier.
Sep 28 - Oct 1	Limited weather support given to white water kayaking competition at Ocoee.
Oct 9 - 15	Limited weather support given to cycling competition at Stone Mountain.
Nov 14 - 16	The November Test.
Dec 18	TDL makes breakthrough with color table conflict.
Dec 19	NCAR declines request to provide Auto-Nowcast software.
1996	
Jan 4	Government shutdown stops work on Olympics preparation activities.
Jan 8	Preparation activities resume.
Jan 17 - 19	The January Test.
Jan 24	Media Day at the OWSO.
Jan 29 - Feb 1	AMS Conference in Atlanta. Papers presented. Booth staffed. Tours given.
Feb 12	IBM approves ACOG's purchase of Meteo 96 software for NWS.
Mar 12 - 14	The March Test.
Mar 31	Lightning strike damages some OWSO equipment.
Apr 7 - 14	Limited weather support given to archery competition at Stone Mountain.
Apr 9	IBM delivers RS/6000 SP computer to OWSO.
Apr 11	Briefing given at NWS Directors' Meeting. Tours of OWSO provided to attendees.
Apr 12 - 22	Limited weather support given to shooting competition at Wolf Creek.
Apr 15	The IBM RS/6000 SP comes on line.
Apr 18	John Chandioux Consultants and ACOG agree on terms for purchase of Meteo 96.
Apr 19	ACOG denies NWS request for Info'96 terminal at OWSO.
Apr 27	NCEP's model distribution system fails due to overload.
May 1	OWSS Hardware/Software Freeze.
May 3	NCEP model distribution functional again.
May 9 - 12	Limited weather support given to Paralympics track & field competition.
May 14 - 16	The May Test.
May 17-18	Limited weather support given to track & field competition at Olympic Stadium.
May 23	MOU between the NWS and IBM finalized.
Jun 27	OWSO and OMWSO forecasters arrive. Training and silent operations begin.
Jul 6	Olympic Villages opened. Official forecast operations begin.
Jul 19	Opening Ceremonies in Atlanta.
Jul 20	Opening Ceremonies in Savannah.
Aug 2	Closing Ceremonies in Savannah.
Aug 3	OMWSO operations cease; shutdown begins.

1996 (cont)

Aug 4	Closing Ceremonies in Atlanta.
Aug 5	OWSO forecasters leave.
Aug 6	PWSO (formerly the OWSO) forecasters arrive for Paralympics weather support training and Olympics draw-down support.
Aug 12 - 25	The Paralympic Games.
Aug 27	PWSO operations cease.
Aug 30	PWSO closes.

3. Infrastructure

a. Background

Weather support for the 1996 Olympic Games began as early as 1989, well before the commitment to support the Games was formalized. In preparing their proposal to host the Games, the Atlanta Organizing Committee (AOC), later known as the Atlanta Committee for the Olympic Games (ACOG), approached the NWS Forecast Office (NWSFO) in Atlanta, Georgia, seeking climatological information. After Atlanta was awarded the right to host the Games, the Atlanta NWSFO assisted ACOG with a variety of weather support issues. For example, ACOG's concern about heat stress at the site of the equestrian event led to NWS collaboration with the University of Georgia in installing automated meteorological observing systems around the state to assist in obtaining climatological information needed for site selection.

b. The Olympic Weather Support Committee

Following the formal request for weather support services, the NOAA Assistant Administrator for Weather Services appointed the Director of the NWS's Southern Region as the Olympic Weather Support Project Coordinator. He also appointed an Olympic Weather Support Committee to assist the Project Coordinator. The Olympic Weather Support Committee (OWSC), which functioned under the oversight of the Project Coordinator, was responsible for working with the ACOG, other elements of NOAA, other Federal Agencies, elements of the World Meteorological Organization, the Canadian Atmospheric Environment Service, the Australian Bureau of Meteorology, the National Center for Atmospheric Research, local government agencies, and the private sector in developing and implementing the plans for the required support.

The OWSC membership was drawn from various segments of the NOAA family, since it was determined early on that the Olympic Weather Support Project would need resources from other segments of NOAA if the NWS's goals were to be accomplished, e.g., fulfilling the mission statement, and achieving the Department's goal of showcasing U.S. advanced technology. The OWSC membership was as follows:

The Olympic Weather Support Committee

Mac McLaughlin	Chairman	Chief of Meteorological Services, NWS Southern Region, Fort Worth, Texas
Christene Alex	Member	Office of Meteorology, NWS Headquarters, Silver Spring, Maryland
Carl Bullock	Member	Forecast Systems Laboratory, OAR, Boulder, Colorado
Laura Cook	Member	Office of Meteorology, NWS Headquarters, Silver Spring, Maryland
Mike Eilts	Member	National Severe Storms Laboratory, Norman, Oklahoma
Carlos Garza, Jr.	Member	MIC, NWSFO Peachtree City, Georgia
Roger Pappas	Member	WCM, NWSO Sacramento, California
Stephen Rinard	Member	MIC, Olympic Marine Weather Support Office, Wilmington Island, Georgia
Lans Rothfusz	Member	MIC, Olympic Weather Support Office, Peachtree City, Georgia
Harvey Thurm	Member	Marine Services Program Manager, NWS Eastern Region, Bohemia, NY
Sondra Young	Member	Lead Forecaster, NCEP, Camp Springs, Maryland

The Committee quickly determined the need to establish two offices to meet the meteorological support requirements, and subsequently developed plans to operate two Olympic Weather Support Offices; one (the OWSO) in the Atlanta area at the new combined weather and river forecast office at Peachtree City, GA, to support the majority of the venues, and the other (the OMWSO) in quarters to be provided by the Olympic Organizing Committee at the Olympic Compound on Wilmington Island, GA, to support the unique requirements of the yachting venue.

A Meteorologist-In-Charge was appointed for each of these two Olympic Weather Support Offices. These two individuals, who were also permanent members of the OWSC, were assigned the responsibility of overseeing the coordinating, planning, developing, and implementation of the day-to-day aspects of the NWS Olympic support activities.

c. Olympic Weather Support Offices

Staffing

The Olympic Weather Support Office

Management and Development Team

Lans P. Rothfusz	Meteorologist-In-Charge
J.T. Johnson	SOO (on loan from NSSL)
Clark Safford	Systems Administrator
Clarence Hall	Systems Administrator
Chris Jacobson	Programmer/Meteorologist

Primary Forecasters

Barker, Llyle	NWSO Goodland, KS
Burr, Christopher	NHC, Miami, FL
Churchill, Brad	NWSFO Norman, OK
Eckert, Michael	NCEP, Camp Springs, MD
Faught, Dianne	CWSU Indianapolis, IN
Flatt, Paul	NWSO Tucson, AZ
Gaudette, Mario	Canada AES, St-Laurent, Quebec
Lachapelle, Andre	Canada AES, Fredericton, New Brunswick
McClung, Tim	NWSFO Los Angeles, CA
Moore, Patrick	NWSO Tallahassee, FL
Noffsinger, Jim	NWSFO Peachtree City, GA
Peters, Brian	NWSFO Birmingham, AL
Ryan, Christopher	Australia BOM, Melbourne, Victoria
Rydell, Nezette	NWSFO San Antonio, TX
Sabones, Mike	NWSFO Indianapolis, IN
Sammler, William	NWSO Wakefield, VA
Schmidt, Craig	NWSFO Portland, OR
Vaillancourt, Pierre	Canada AES, St-Laurent, Quebec
Young, Sondra	NCEP, Camp Springs, MD
Wagner, A. James	NMC, Camp Springs, MD (ad hoc member)

Paralympic Forecasters and Olympic Alternates

Abeling, William	NWSFO Bismarck, ND
Cooper, Steven	SRH, Fort Worth, TX
Frantz, Kent	NWSFO Peachtree City, GA
Hoxsie, Kathy	CRH, Kansas City, MO (Olympics alternate only)
Wilson, William	NWSFO Louisville, KY (Paralympics only)
Zaleski, Walt	NWSO Tampa Bay, FL

The Olympic Marine Weather Support Office

Management and Development Team

Steven K. Rinard	Meteorologist-In-Charge
Mario Valverde	Systems Administrator
Bruce Marshak	Assistant Systems Administrator

Primary Forecasters

Barnes, Wally	NHC, Miami, FL
Neault, Gerard	AES, Vancouver, BC
Niziol, Thomas	NWSFO Buffalo, NY
Powell, Mark	AOML, Miami, FL
Spark, Elly	BOM, Sydney, New South Wales
Spratt, Scott	NWSO Melbourne, FL
Townsend, John	NWSO Charleston, SC

4. Customers & Requirements

a. Background

The celebration of the modern Olympic Games is a major international event, drawing not only thousands of athletes, but heads of state, hundreds of thousands of spectators, and, via television, a global audience of millions. It is estimated that approximately two million people attended the 1996 Games. At any given time during the course of the 1996 events, anywhere from 250,000 to 500,000 people were exposed to the elements, either by being in attendance at outdoor Olympic venues, or by being en route to indoor facilities, housing, and other activities. At the yachting venue, the United States Coast Guard estimated that as many as 1000 small boats were plying the coastal waters off the southeast Georgia coast to gain vantage points from which the competition could be observed.

The 1996 Games were held in a part of the United States which can be very active, meteorologically, during the summer months. It followed then, that the weather would likely have a significant impact on the Games at one time or another. Considering the number of people who would be at risk if an inclement weather episode impacted the Games, it was clear that accurate and timely weather information was essential for the protection of the athletes and spectators, and for the safe conduct of the sporting events.

The customers of Olympic weather support information were varied. Competition managers, especially those in charge of events conducted out-of-doors, required different types of weather information. For example, officials in charge of the diving competition were concerned about wind speed (among other things). Those in charge of tennis were concerned about any precipitation which might occur, while cycling officials needed information about the atmospheric moisture content, since dew formation on the track caused it to become slippery and dangerous. All competition managers were concerned about lightning and other types of severe weather, since they were involved in making decisions concerning the postponement or cancellation of events. Another type of customer was the Venue Manager. These officials needed weather information in order to plan transportation, security, and vending operations at the venues; to activate sheltering plans for spectators and support staffing should severe weather threaten; to schedule additional medical personnel and availability of additional water supplies in the event excessive heat was forecast, etc. To assist the officials in interpreting and using the weather information, they were provided a customer training document (see Appendix A). This document gave examples of the type of weather warnings, forecasts, and summaries generated by the OWSOs, and provided information to assist customers in using that information. Copies of the document were supplied to all venue and competition managers.

Customers of weather information were not limited to ACOG Venue and Competition Managers. Those in charge of overall transportation needed weather information in order to adjust schedules if the weather resulted in cancellation or postponement of events, and transportation routes had to be altered in the event rain caused localized flooding of roadways or traffic congestion. Emergency Management officials needed weather information so that emergency action plans could be activated if needed. The Secret Service needed to plan for the movement and protection of heads of state and other domestic and international dignitaries. Medical authorities required weather information in order to plan for the provision of medical supplies and the scheduling of medical personnel in the event of weather emergencies. Police and fire departments needed the information to facilitate the scheduling and positioning of equipment and personnel. Coaches and athletes used weather information to plan strategies for competition; even to the detail of planning the type of food which was be consumed by the teams. Spectators used the information to plan their daily activities during the course of the Games.

To meet these requirements for essential weather services, the National Weather Service provided weather support for the Games in three areas;

- Support was provided to ensure that adequate warning and forecast services were available to provide for the protection of the athletes and the spectators.
- Support was provided to satisfy requirements at the various venues for meteorological data to assist ACOG officials in weather contingency planning necessary to ensure the safety of athletes, spectators, and others.
- Meteorological support was provided to meet the requirements of the various International, Federal, State, and Local entities which provided logistical support to help ensure the safe conduct of the Games.

The following mission statement was adopted to summarize the goal of the National Weather Service's Olympic Weather Support Project:

> ***The National Weather Service dedicates the world's best meteorological science, skill, service, and technology to keep the 1996 Games weatherwise and weathersafe.***

b. The Olympic Weather Support Office - Supported Venues

Through considerable interaction between the NWS and ACOG, the unique needs of the Olympic officials were determined. Most Olympic venues needed specific and non-standard information. Some examples of the non-standard information were:

* The banked bicycle track (velodrome) could not be used if the track had any moisture on it (condensation or precipitation); thus, Dew Formation Warnings were requested.
* The flat-water rowing and canoeing competitions were adversely affected by winds more than 10 mph; thus, Wind > 10 Warnings were requested.
* Equestrian competition courses were chosen based on the amount of cloud cover (more difficult courses for cloudier days). No warnings were devised for this need, but extra care was given to the 3-hourly cloud forecasts for the coming day.
* Wind direction changes > 90 degrees adversely affected track and field and flat-water rowing competitions; thus, Wind Direction Change Warnings were requested.

* Wind > 20 mph would delay diving competition; thus, Wind > 20 Warnings were requested.
* Any rain could delay baseball and softball competitions; thus Rain Warnings were requested.
* Occurrence of lightning would result in an evacuation of the field of play and/or the spectator areas; thus Lightning Warnings were requested.

☆[3] **Frequent and early interaction between the NWS and ACOG resulted in improved support. The interaction included assisting Olympic officials in the development of Weather Action Plans which linked actions their people should take based on the information the NWS provided.**

The venues for the 1996 Olympic Games were not just located in metropolitan Atlanta. Many were in the surrounding areas of Atlanta, while others were well-removed from Atlanta. Figure 1 shows locations of the venues, which stretched from the Ocoee River in southern Tennessee to Columbus in the west to Athens in the east and to Savannah in the south. Thus, many venues had vastly different conditions while others had only subtle differences. All 36 venues were combined into ten "venue clusters" as depicted in Fig. 1. Most of the clusters contained only one or two venues while the "Olympic Ring" cluster contained the metropolitan venues.

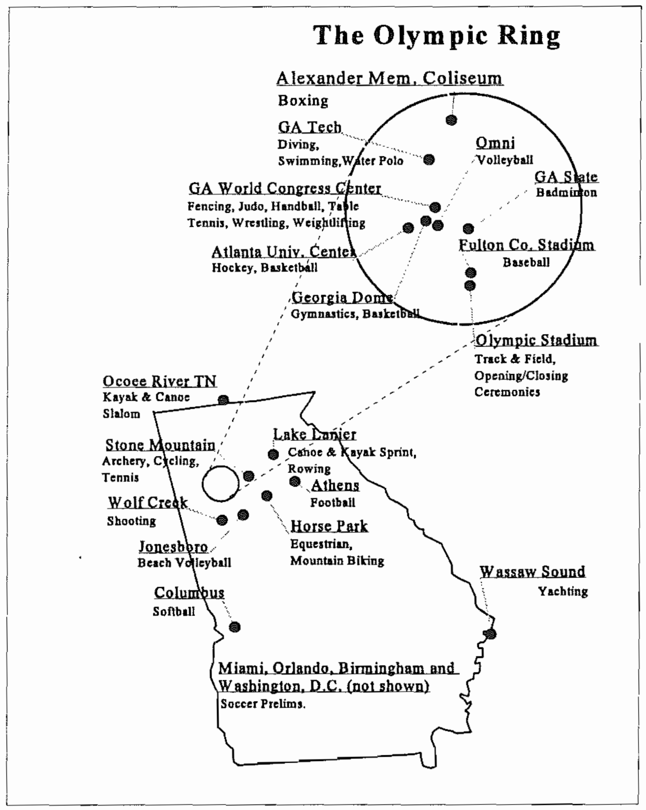


Fig. 1 Locations of Olympic venues and sports.

ACOG

The Atlanta Committee for the Olympic Games was the primary customer of OWSO services and products. The officials, athletes, coaches required weather information for their safety and the smooth operations of the Games.

Each venue had a supporting Venue Communications Center (VCC). Some venues shared a VCC, but most had their own. The purpose of the VCC was to serve as a clearinghouse for all information about security, crowd control, emergency communications, medical needs, as well as weather. Watches, warnings and statements faxed

---

[3] Sections highlighted in bold print and denoted with a star (☆) document significant successes and/or positive aspects of the project. Sections highlighted in bold print and denoted with an ✘ document either less successful aspects of the project or areas where a different course of action would have been preferable.

to a VCC were to be communicated by the VCC to the appropriate Venue Manager(s), Competition Manager(s), security, law enforcement, medical and other appropriate individuals on-site. The VCCs supported by the OWSO are listed below.

Cluster #1: Olympic Ring
- Accreditation Center
- Airport Welcome Center
- Alexander Memorial Coliseum
- Aquatic Center
- Atlanta-Fulton County Stadium
- Centennial Olympic Park
- Clark-Atlanta Univ.
- Family Hotel
- Georgia Dome
- Georgia State Univ
- Georgia World Congress Center
- International Broadcast Center
- Main Press Center
- Marathon Course
- Morehouse College
- Morris Brown College
- Olympic Stadium
- Olympic Village
- Omni Coliseum
- Racewalk Course
- Road Cycling Course

Cluster #2: Stone Mountain
- Archery & Velodrome
- Tennis Center

Cluster #3: Horse Park

Cluster #4: Wolf Creek

Cluster #5: Atlanta Beach

Cluster #6: Lake Lanier

Cluster #8: Columbus Golden Park

Cluster #9: U of G - Athens
- UGA Coliseum
- UGA Sanford Stadium

Cluster #10: Ocoee

High-level officials of ACOG resided in downtown Atlanta in a facility called The Center, a command center for all VCCs. Although The Center had access to Info'96 (see below), the OWSO faxed periodic weather summaries to this site. In addition, video-teleconferencing capability was established between the OWSO and The Center in the event that immediate weather briefings were needed.

The President of the International Olympic Committee and his staff resided in the Olympic Family Hotel (Marriott) in downtown Atlanta. Face-to-face weather briefings were originally to be given to ACOG officials each morning and they, in turn, were to brief Mr. Samaranch and his assistants. This did not pan out due to changes in ACOG procedures; consequently, weather briefings for ACOG were conducted by phone early each morning.

Info'96

Info'96 was the primary medium by which the media, athletes, trainers, Olympics officials and families of athletes received weather information. Developed by IBM, Info'96 was a network of personal computers distributed throughout the Olympic venues and served by an IBM AS/400. In addition to weather data, Info'96 provided athlete biographies, competition results, and transportation schedules. A dedicated line linked Info'96 to the Olympic Weather Support Office and the Olympic Marine Weather Support Office.

ACOG and the NWS collaborated extensively on the development of the weather database and user interface of Info'96. As a result, Info'96 was designed to accept NWS textual data and convert them into easily-understood graphics. For example, forecasts of three-hourly temperatures in matrix format were displayed by Info '96 as 24-hour time series graphics. Notably, the time series included observed temperatures and forecast temperatures.

☆ **While such graphics did not directly compare observed temperatures with forecasts valid earlier than the present time, any large discontinuity between past and forecast temperature lines would have been noticed. This served as added incentive for forecasters to routinely monitor the quality of their forecasts.**

✘ **In most of the software applications, Info'96 suffered significantly in the early stages of the Games. The system was not ready for implementation as the Games began and customers were unable to access the much-advertised information (weather data included). System stability improved after the first five days of the Games, but by that time, Info'96 customers were reluctant to rely on it. As a result, the OWSO was forced to fax forecasts to the VCCs which overwhelmed the faxing software and hardware.**

☆ **Ironically, Info'96 was the medium best suited for the quantity and type of weather information being provided (e.g., when compared to NOAA Weather Radio and Family of Services). Once it began working properly, Info'96 customers could quickly access the information they wanted and in a highly-detailed format.**

A request was made to the ACOG to place an Info'96 terminal at the OWSO. ACOG denied the request. Subsequently, volunteers were selected to quality control the OWSO and OMWSO products. The AM/MIC, NWSFO FFC, worked with the ACOG to locate and organize these volunteers.

☆ **Due to the problems with Info'96 development, the QC volunteers proved crucial to ensuring quality weather information being disseminated via Info'96. These volunteers had meteorological backgrounds which helped them identify unrealistic or questionable data.**

From the very outset of its development, Info'96 developers said that their system would not be used as an "emergency information" system. Thus, all warnings sent to Info'96 also were faxed to the appropriate VCC. This provided a level of redundancy important in short-fused warning situations.

Non-ACOG Groups

In addition to the customers listed above, several agencies were provided weather support from the OWSO. The support included periodic (and is some cases routine) faxes of textual data and on-demand weather briefings via telephone. The following paragraphs describe most of these customers.

The Joint Communications Center (JCC) was established in Atlanta's City Hall East. This facility housed representatives from such agencies as the Secret Service, FBI, Georgia Highway Patrol, Atlanta Police Department, National Guard, FEMA, Georgia Emergency Management Agency, and others. The purpose of the JCC was to serve as a clearinghouse for all Olympic support information to the law enforcement and Emergency Management agencies.

In addition to the JCC, there was a state-level law enforcement center called SOLEC. NWS personnel from the NWSFO, led by the NWSFO MIC, were on-site at the SOLEC for interaction with officials there. Also, the Olympic Intelligence Center for intelligence-related federal agencies was established at an undisclosed location.

The main military command center for the Olympics was located at Ft. McPherson in southwest Atlanta. Security and logistical support was provided to the Games by the military. Coordination of these activities for all venues and surrounding areas took place from the Joint Task Force (JTF).

✘ **The JCC was originally billed as the sole clearinghouse for law enforcement and security agencies. In the months leading up to the Games, jurisdiction disputes led to the formation of multiple "coordination centers". This complicated the ability of the OWSO to get weather information communicated to an ever-expanding customer base.**

☆ **During Hurricane Bertha and after the Centennial Olympic Park bombing, NWS representatives stationed at SOLEC provided valuable weather support to the law enforcement community.**

✘ **Most law enforcement and military organizations relied upon Family of Service vendors for their weather information. Some vendors providing this service could not make the Olympic products available to specific users without impacting all users. Also, the volume of data issued by the OWSO became overwhelming to customers who could access the Olympics data.**

The NOAA Air Resources Laboratory (ARL) collected Regional Atmospheric Modeling System (RAMS) data periodically from the OWSO, and ran dispersion models for evaluating the contaminant flow in the event of a nuclear or chemical incident.

The Defense Nuclear Agency made arrangements with the OWSO to acquire RAMS data from the ARL, as well as acquiring mesonet data directly from the OWSO periodically to model nuclear or chemical releases.

Finally, all textual data generated by the OWSO were made available to the media via standard Family of Service connections. The WMO headers for these data were announced via Public Information Statements. Fig. 2 summarizes the flow of data.

c. The Outlying Venues

Preliminary Olympic soccer competitions were held in locations outside Georgia, namely Birmingham, AL; Orlando and Miami, FL; and Washington, D.C. Weather support for these sites was provided by the NWS offices which normally support those locations (see below). ACOG referred to these venues as "satellite venues;" therefore, the offices supporting them were called "Satellite Olympic Weather Support Offices" (Satellite OWSOs).

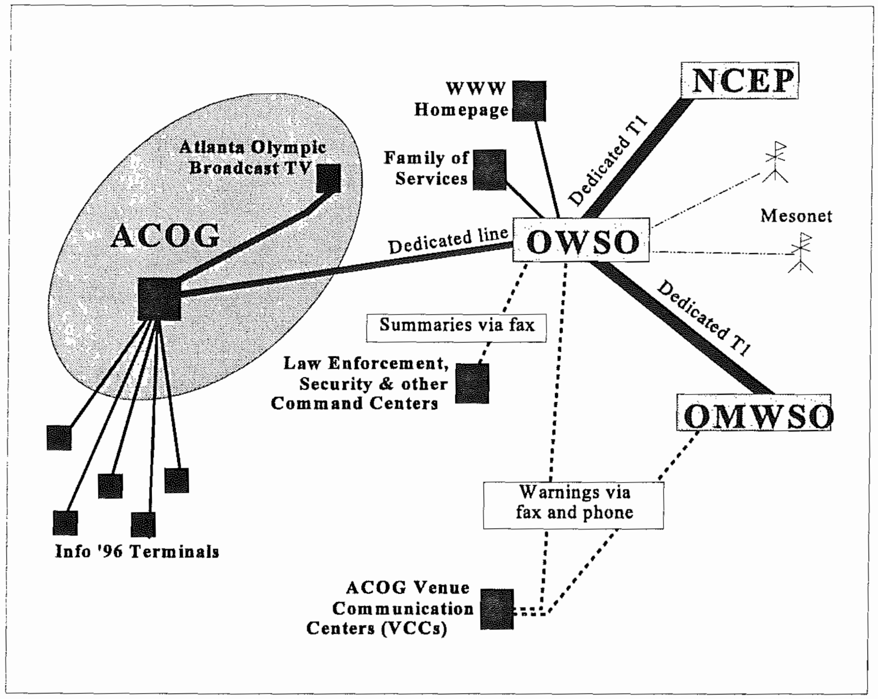


Fig. 2 Flow of data to external customers and from data sources.

Venue Location	Support Office
Legion Field, Birmingham, AL	NWSFO Birmingham
Orange Bowl, Miami, FL	NWSFO Miami
Florida Citrus Bowl, Orlando, FL	NWSO Melbourne
RFK Stadium, Washington, D.C.	NWSFO Sterling

d. The Yachting Venue

The Yachting Venue was one of the most weather sensitive of the Olympic venues due to the broad range of weather- and oceanographic-related parameters affecting the venue. These parameters included wind, waves, thunderstorms, sea breeze, tropical cyclones, ocean currents, tides and visibility. Many of these phenomena were always present. While infrequent, some were a matter of venue and personnel safety, and could have resulted in discontinuation of venue operations. Finally, the lack of a sea breeze/wind would also terminate competitions.

Depending on the class of boat scheduled to race, the minimum wind speeds needed for competition were 6-8 knots with a maximum speed no greater than 20 knots. Waves began to adversely affect yachting competitions when wave heights reached 5 to 6 feet. While some classes of competition can operate in the more extreme wind and wave ranges, the support and committee boats would have problems maintaining the course if conditions became too rough.

To address these sensitive weather and oceanographic parameters, several key requirements were identified that were needed to meet the weather needs of the Yachting Venue. (1) The Olympic Marine Weather Support Office should be located within the Yachting Venue in order to maintain close liaison with Venue and Competition Managers. (2) A marine mesoscale observation network was needed to support the high resolution needs of the venue meso-forecasting program. (3) WSR-88D radar coverage over the venue was required for the warning program. (4) Part of the forecast team should operate within the offshore field-of-play observing actual conditions and working directly with the venue management team located during race times on Wassaw Sound.

5. The Olympic Weather Support System

a. Software

The OWSO and OMWSO shared a common set of hardware and software known as the Olympic Weather Support System (OWSS). The OWSS's software comprised the following components.

N-AWIPS

N-AWIPS is comprised of software that ingests, analyzes, displays and integrates various types of hydrometeorological data. These data types include numerical model, surface, upper-air, satellite, radar and text data. N-AWIPS runs on UNIX workstations that support X-Windows and Motif. The N-AWIPS software was developed by the National Centers for Environmental Prediction (NCEP).

N-AWIPS includes the General Meteorological PAcKage, (GEMPAK) software and a set of graphical user interface (GUI) programs. The GEMPAK software provides much of the N-AWIPS core capabilities including data decoding, data analysis, navigation and display capabilities. GEMPAK includes a comprehensive set of meteorological parameter calculations for surface, upper-air, and gridded data. Multiple map projections are supported and data can be displayed by user-defined geographic regions. Satellite and radar imagery may be subsetted and displayed with graphic overlays (e.g., geography, contours, etc.). Graphics and imagery can be animated and color enhanced.

The N-AWIPS GUI programs provide an easy-to-use interface to some of the GEMPAK capabilities. These programs include the AFOS emulator; NSAT; NTRANS; and NWX.

The AFOS emulator displays graphics and text products from the AFOS data feed. A Motif graphical user interface controls the program functions. The AFOS emulator provides a means for the forecasters to view standard NWS products available on the AFOS circuit. Originally developed at the River Forecast Center in Tulsa, OK, it has been enhanced and integrated with the N-AWIPS software.

NSAT displays and animates satellite imagery. A Motif graphical user interface is used to control the program functions. Some satellite data are provided to NSAT by NCEP. Additional data are supplied to the RAMM Advanced Meteorological Satellite Demonstration and Interpretation System (RAMSDIS) by the Storm Prediction Center (SPC) or NESDIS. These data are, in turn, converted into a format usable by NSAT.

NTRANS displays and animates N-AWIPS graphics metafiles. The program is primarily used to display model fields generated by the N-AWIPS and GEMPAK software. NTRANS allows the selection of graphical products from a set of metafiles stored in the database.

NWX is a graphical interface used to select text products for display. Text products that can be represented at individual locations, e.g., MOS data, are plotted as markers on a map. The text products are displayed in a text window by clicking on the desired marker with the cursor mouse. The program allows selecting data by station or state. Different map regions and zooming options are available.

☆ **N-AWIPS performed well. NTRANS was used most frequently and was most appreciated for its ability to time lapse and compare multiple models. The NWX was extremely well-received due to its ease of accessing textual data. NSAT and AFOS Emulator were used very little because their data could be acquired via other sources.**

✗ **From an operational point of view, N-AWIPS supports synoptic scale forecasting well. As its developers agree, however, N-AWIPS was not designed for mesoscale forecasting operations. Because meta files (graphic images) are predefined, forecasters had no real-time control over domain, contour intervals, data combinations, etc. This was particularly frustrating when localized phenomena such as fog formation or convective initiation were being forecast. Although N-AWIPS is a solid, well-conceived system for its purpose, the intense mesoscale forecasting required of the Olympics forecasters was beyond what it was designed to deliver. Lack of data display control precluded more effective mesoscale forecasting. In a mesoscale forecasting situation, *forecasters must have the ability to control the domain, contours, appearance and combinations of graphical data in real-time.***

LAPS

The Local Analysis and Prediction System (LAPS) was developed at NOAA's Forecast Systems Laboratory (FSL). It is designed to produce high-resolution analyses and forecasts while running on a computer in a local forecast office. LAPS uses all the data available to the local office, such as WSR-88D velocity and reflectivity, surface observations (both METARs and local mesonetwork sites); satellite; aircraft; wind and temperature profilers; and background fields from other numerical models. Analyses of standard measured and derived variables at both surface and upper-levels are produced. These analyses are available for display and are used as initial conditions for the predictive component of LAPS (RAMS).

☆ **All but one forecaster cited LAPS as a critical tool in all mesoscale forecasting situations. The 30-minute analyses were used extensively and undoubtedly improved the quality of the weather support. Forecasters found the most useful fields to be divergence, wind vectors, CAPE and θ_e.**

Interactive Sounding Program

The Interactive Sounding Program (ISP) has new capabilities over its PC-based cousin, SHARP (Hart and Korotky 1991), including multiple sounding overlays and improved features for determining convective potential. Essentially, ISP is a UNIX version of SHARP.

✘ **The weakest aspect of ISP was that it could not be run simultaneously with some other applications due to color table conflicts. Thus, ISP was used only sparingly, despite much-desired regional upper-air data being available four times daily. One sure way to prevent a tool's use was discovered - make it conditionally accessible.**

ICWF

The Interactive Computer Worded Forecast (ICWF) software is a family of techniques that enables forecasters to interactively prepare digital forecasts of weather elements from which routinely-issued products can be automatically composed and formatted (Rothfusz , et. al., 1996b). These were the primary techniques for preparing routine forecasts at the OWSO. These techniques allowed forecasters to concentrate on the meteorology of the situation by relieving them of the need to type products in different formats. The common database used to generate these products also allows for more consistent forecasts over time and among products, and for easier monitoring and maintenance of those forecasts.

Three steps characterize the ICWF process. First, ingest programs initialize forecast grids from various guidance sources as these data arrive. Second, interactive programs allow the forecaster to modify gridded forecasts and venue forecasts. Third, product generation programs use the values stored in the digital database to produce a variety of forecasts. The ICWF was developed by the Techniques Development Laboratory (TDL).

☆ **Most forecasters agreed that ICWF was essential to creating better all-around forecasts because it saved time, generated more detailed forecasts, and allowed forecasters to focus on meteorology rather than typing. Customers of ICWF products responded enthusiastically to the level of detail they received.**

✘ **Some forecasters had difficulty making the narrative text "say" what they wanted, partly because of stylistic preferences, but mostly because ICWF's customization for the Olympics spawned bugs not found with the standard ICWF package. Because of these bugs, some forecasters felt ICWF's *only* benefit was as a vehicle for putting their forecasts in the required highly-detailed formats, and that it did not allow them to spend more time on meteorology. Nevertheless, the Olympic experience suggests that customers are better served with greater-detailed products using present-level meteorology than with better meteorology in products at their present level of detail.**

WWA

The TDL-developed Watch Warning Advisory (WWA) software, affectionately called "wa-wa," was used to issue Olympic watches, warnings and statements. It functions very much like ICWF by using the same database of information and similar map functions. Initially intended for issuing long-fused warnings such as Winter Storm Warnings, many changes were made to the WWA software to handle the specialized and pin-point warning types for the Olympics.

The WWA software has several effective tools. WWA keeps track of watches and warnings in effect and signals when follow up statements are needed - very important for the OWSO's 10-15 minute update frequency. It also has a cancellation feature, a clearing feature (for ending a watch or warning for some locations but remaining in effect for others), a simple text product editor, canned call-to-action statements, and easy procedures for product transmission

- ☆ **The point-and-click features of a graphical user interface made WWA extremely user-friendly and forecasters responded quite favorably to its utility. The ability to issue a warning from the same screen displaying radar data was invaluable. The VCCs were extremely pleased with the rapid-fire updates which were made possible by WWA's ease of use.**

- ☆ **WWA's routinely alerting forecasters of the need for update statements contributed to the success of providing rapid-fire updates. Without such a feature, forecasters would tend to lose track of time and products would not be updated with sufficient frequency.**

- ✗ **The only drawback to WWA was the speed at which products were generated. It sometimes took as long as 30 seconds to generate a bulletin template - an eternity to a forecaster in a hurry.**

WDSS

The Warning Decision Support System (WDSS), developed by the National Severe Storms Laboratory (NSSL), applies state-of-the-art algorithms to the WSR-88D data, lightning data, surface observations and uses an innovative display tool to provide a warning meteorologist with the needed information for making warning decisions. As the "next generation" of NEXRAD algorithms, WDSS displays cell attributes in clear, well-organized tables and displays multiple images in an X-Windows environment.

- ☆ **Without a doubt, WDSS was the most-utilized and most popular Olympic Weather Support System program. The interface was intuitive and forecasters rapidly became accustomed to operating multiple windows during widespread weather events. If there is one piece of software that contributed most to the success of the Olympic weather support, it was WDSS. Forecasters identified numerous features of WDSS that they liked, including trends, zooming, cell ranking, lightning overlays, and more.**

- ✘ **The only forecaster criticisms of WDSS regarded the size of the data on the screen, and that output needed to be displayed on a dedicated screen, i.e., WDSS could not easily share a screen with other software - it was too "busy".**

RAMSDIS

RAMSDIS was the only tool not fully integrated into the OWSS. While N-AWIPS software provided a satellite imagery display with looping, enhancement and zooming capabilities, RAMSDIS was chosen as the primary satellite imagery display tool because it provided several added features including rapid selection of products, easy color enhancement manipulation, pixel readout, feature arrival time calculations, and a user-friendly interface for "rapid-scan" imagery (7.5 minute resolution). These additional features outweighed the drawback of not having these features integrated into the HP workstations.

The RAMSDIS workstation utilizes McIDAS-OS2 satellite data ingest capabilities. The NOAA/NESDIS/RAMM Branch and CIRA made several additions to McIDAS-OS2 which allowed for display and analysis of high-resolution digital satellite imagery. These additions included an image display in SuperVGA (SVGA) mode (640x480 pixels with 256 colors), a separate image and text monitor, erasable graphics, and a user-friendly menu system accessible via function keys. Nearly 200 image frames were available on the workstation. RAMSDIS allows for customized product ingest at each forecast site, and includes several satellite data analysis applications developed at the CIRA/RAMM Branch.

The RAMSDIS in the OWSO was configured to receive GOES-8 imagery every 15 minutes from the satellite downlink system at the Storm Prediction Center, then located in Kansas City, MO. The RAMSDIS also provided satellite data to the LAPS analysis, WDSS, and NSAT.

- ☆ **The range of imageries available, the 15-minute ingest frequency and the ability to enhance imagery on-the-fly were wildly popular features among the forecasters. RAMSDIS, along with WDSS, formed the core of the OWSO warning operations, although forecasters deemed RAMSDIS useful in all meteorological situations.**

- ☆ **It was serendipitous that RAMSDIS was not integrated into the OWSS because several forecasters noted how helpful it was to have a stand-alone satellite display constantly looping images nearby. This further supports the need for multiple workstation monitors. The functionality and data accessibility of RAMSDIS virtually eliminated the need for NSAT (on N-AWIPS).**

Coach

Coach is a Performance Support System (PSS) created by the development team of the OWSO. It is driven by html-based software such as that used in homepage applications. The hypertext links of the html software gave access to data which provided immediate forecasting experience in certain weather situations. These data were based on the OWSO forecasters' 1995 contributions to *The*

Forecaster's Journal, a WordPerfect file, which were edited, compiled and organized into manageable components.

Coach prompts the user for selection of general descriptors of the synoptic pattern, mesoscale pattern and forecast problem of the day. Based on the selections made, the appropriate forecast rationale and post-event observations (made by OWSO forecasters in 1995) are displayed along with relevant model, satellite, and/or observational data, if available. Used in real time, forecasters gain the benefit of someone else's experience in a similar weather situation. At a minimum, Coach gives forecasters the ability to compare their formative forecast rationale with that of someone who worked a similar meteorological situation and witnessed first-hand the validity of their rationale in that situation. Ideally, then, the "real-time" forecaster could modify his/her thinking and/or data evaluation based upon the "experience" imparted by Coach.

☆ **Virtually all forecasters (and other visitors to the OWSO) recognized the potential value of a fully-configured Coach. Features such as instant recall of archived satellite and model data were particularly appealing.**

✘ **Forecasters did not find Coach useful in the operations because of the lack of sufficient data in the database. More cases are needed to make Coach a viable forecasting tool.**

GARP

GARP (GEMPAK Analysis and Rendering Program) is an X-Windows/Motif software application designed by the COMET staff for the display and analysis of meteorological data sets. Supported data sets include model data, satellite imagery, NIDS and Nowrad radar data, surface data and upper air data. As an application, GARP is layered on top of GEMPAK. GARP uses Motif to create a point-and-click GUI front end for the display and analysis capabilities of GEMPAK. GARP attempts to make it easy to manage, integrate and visualize multiple meteorological data sets.

✘ **GARP was a late-comer to the OWSS and, as a result, was not quite ready for operational use. Although forecasters found favor with specific features and applications such as zooming and contour controls, the inability to easily time-match images of different types precluded its extensive use. Forecasters felt the GARP design was better suited for mesoscale forecasting than N-AWIPS, but not enough of its features were functioning to make it an attractive tool.**

OWSO GUI

GEMPAK data sets were accessed interactively via scripts and a simple GUI developed for these scripts. The interactive scripts allowed the user to look at the GEMPAK data sets in ways that could not be easily automated. The GUI was a simple menu listing of the scripts and a series of cascading menus for each type of script.

Visualization Data Explorer™

Visualization Data Explorer™ (also called DX) is an off-the-shelf, 3-D visualization program contributed by IBM. It was used to create high-quality 3-D representations (and animations) of RAMS output for display to the media. It also has practical applications for forecasters, but lack of time to develop an operational application precluded its extensive use in this area. As it was, IBM contributed a programmer to develop the user interface and establish standard imagery controls for displaying RAMS and Eta-10 data. Extensive collaboration took place between the NWS and IBM in this endeavor. DX was loaded on the Prometheus (IBM) workstation located in the Media Room.

- ☆ **Media visitors were exceedingly impressed with the DX images of RAMS. Data were presented in a way easily understood by non-meteorologists. Most popular were the 3-D animations of model clouds, rain (dBz, actually), total precipitation and winds. Representations of sea breezes were also quite dramatic.**

- ☆ **Reaction among the forecasters varied widely. Those who used DX extensively found ways to use the imagery in the creation of their forecasts. Other, less-experienced DX users had unfavorable impressions of the imagery - mostly due to the slow speed at which the images were generated. Most forecasters agreed, however, that user-specified, 3-D animations of model data were a significant improvement over 2-D imagery. In fact, some vital information could be gleaned from the 3-D imagery that could not be found in current 2-D imagery (e.g., cloud water and radar reflectivity forecasts).**

- ✘ **Forecasters found the DX software to be slow and with a slightly confusing user interface. Also, fly-over animations were of little value to forecasting operations.**

- ✘ **Due to the problems in obtaining Eta-10 data reliably, and the late arrival of DX, code could not be written to create 3D Eta model images. Thus, no 3D animations of the Eta model were available.**

Meteo 96

French/English translation software available from John Chandioux Consultants, Inc. was purchased by ACOG for use by the NWS during the Olympics. Since French and English are the two official languages of the Olympics, all weather information appearing on Info'96 was required to be available in both French and English. The PC-based Meteo 96 was adapted from similar programs used by the Canadian Atmosphere Environment Service (AES) and installed in the OWSS. In addition to guaranteeing a 90% translation accuracy rate, Meteo 96 was also configured to convert English units to metric. This latter feature was 100% accurate.

- ☆ **The Meteo96 translation was successful due to the preparation in developing the product. Sample forecasts, watches, warnings, call-to-action statements, and lists of venues where provided to John Chandioux Consultants before the software**

was installed. This preparation allowed the translation meteorologists to adequately keep up with the forecasts, watches, and warnings that were issued.

- ☆ **Each AES meteorologist edited an average of three thousand words of English and eight thousand words of French per shift. John Chandioux Consultants estimated that it would have taken a team of twelve full-time technical translators (four per shift) to do the job manually and warnings would have been obsolete by the time the translation became available.**

- ☆ **John Chandioux Consultants, Inc. were exceptional partners in this endeavor. They continuously updated their software, even through the Paralympics. They also modified the code to make Meteo 96 work more effectively on the OWSS.**

- ☆ **Subjectively, the accuracy rate of translation was about 80%, but it improved over time. Still, that rate usually allowed the translator to keep pace with the volume of products that were being issued during active weather situations.**

b. Hardware

The hardware of the OWSS was comprised of single-monitor, 9000 Series HP workstations (715 or 755 models). The 715s and 755s had 64 and 128 Mbyte of RAM, and 2 and 4 Gbyte internal disks, respectively. External hard disks added another 15 - 20 Gbyte to some of the machines. The 755 models were used as servers and data processors while the 715s were forecaster workstations. In general, this configuration worked well.

- ✗ **The most common complaint about hardware among forecasters was the lack of a second monitor. Although each X-Windows environment had six work spaces in which most OWSS applications could run simultaneously, there was still a need to *see* multiple programs at the same time.**

The following equipment comprised the OWSS:

Device	Purpose
HP 755 Workstation (Scotty)	Forecaster workstation and backup server
HP 715 Workstation (Klingon)	Forecaster workstation
HP 715 Workstation (Ferengi)	Forecaster workstation
HP 715 Workstation (Uhura)	Forecaster workstation
Gateway Pentium PC & 2 monitors	RAMSDIS
Pentium PC and modems	Meteo 96, GA Forestry mesonet collection, Info'96 data dissemination
HP 4M Laser Printer	Hard Copy
Fax machine	Receive and send faxes

The following OWSS equipment was outside the operations area at the OWSO:

Device	Purpose	Location
HP 715 Workstation (Trekie)	Media display	Media room
IBM 39H (Prometheus)	Media display	Media room
37" NEC Monitor	Media display	Media room

Device	Purpose	Location
Color Printer	Color Prints	Media room
HP 715 Workstation (Bones)	Test & evaluation	NWSFO ops area
HP 715 Workstation (Sulu)	Server	OMWSO
HP 715 Workstation (Borg)	Forecaster workstation	OMWSO
HP 715 Workstation (Kirk)	Forecaster workstation	OMWSO
Pentium PC (Hadrian)	Firewall	Equipment room
Alantec PowerHub	Comms hub	Equipment room
Cisco Router	Router	Equipment room
SunSparc 5	WDSS data ingest	Equipment room
SunSparc 20 Workstation	WDSS algorithms	Equipment room
HP 755 Workstation (Spock)	OWSS server/sys admin	OWSO "annex"
Pentium PC and two modems	Mesonet data collection	OWSO "annex"
Pentium PC	Forecaster Applications	OMWSO
SunSparc 5	WDSS data ingest	CHS WSR-88D RPG
SunSparc 20 Workstation	WDSS algorithms	CHS WSR-88D RPG
Pentium PC	Buoy data processing	OMWSO
HP Laser Jet4	Hard Copies	OMWSO
Gateway Pentium PC	RAMDIS	OMWSO

"Spock" was the data server for the rest of the network and ran the local data manager (LDM). It handled all model data arriving from NCEP, text data from AFOS and some satellite data also from NCEP. All of the HP workstations served as displays for N-AWIPS, WDSS, ICWF, WWA, etc.

The SUN workstations were for the WDSS. A SUN SparcStation 5 was connected to the Wideband 3 User Port on the Peachtree City WSR-88D. This machine then distributed Level 2 radar data to a SUN SparcStation 20 which served as the UNIX-based Radar Products Generator, running the enhanced NSSL severe weather detection algorithms. A SUN SparcStation 5 was also connected to the Wideband 3 User Port on the Charleston, SC, WSR-88D.

c. Communications

A dedicated T1 line from NCEP to the OWSO, a second dedicated T1 from the OWSO to the OMWSO and a 128 KB line from the Charleston, SC WSR-88D radar to Savannah formed the backbone of communications for the Olympic weather support. The T1 lines were used to:

1. Ingest numerical model data, text data and satellite imagery from NCEP;
2. Ingest satellite imagery from NESDIS and the Storm Prediction Center (SPC - Kansas City);
3. Transfer data between the OWSO and the OMWSO;
4. Provide a connection to the Internet.

In the event of catastrophic failure of the T1 line to NCEP, a frame relay from Fort Worth was configured to handle some of the data load until the T1 link could be re-established.

The primary means of receiving data for the OWSS was via the Local Data Manager (LDM). Data received from NCEP utilized two methods: a) an alert system for gridded model data and satellite imagery, and b) a backup system for gridded model data and satellite imagery. AFOS data (text and graphics) were ingested into the OWSS via an AFOS Protocol Translator (APT) using a serial port of the OWSS primary server. Local mesonet data collected by PCS were brought into the LDM via a serial port on the OWSS primary server and LDM's 'pqingest' software. All LDM data fed into the primary server were sent downstream to the backup server and to the OMWSO.

The primary data flow system between NCEP and the OWSS was based on DBNet (Distributed Brokered Networking) developed by NCEP/NCO, residing on a UNIX workstation (olympic1), located at NCEP. Model data generated on Cray computers located at NCEP and Cray Research, Inc. (Eagan, Minnesota) initiated "alerts" indicating data availability which created a processing/communication chain. The "alert" chain is grossly described as:

1. Alerts received by DBNet on olympic1.
2. Model data availability checked on olympic1.
3. Alerts are sent to a modified DBNet version, (will be referred to as the OWSS DBNet), using LDM version 5.0 as its transport.
4. OWSS DBNet profiles and prioritizes alerts.
5. Model data availability checked on OWSS computers.
6. Continuation of the alert chain to other computers and/or dispatching of local codes (which may or may not result in a new alert chain).

NCEP also provided a backup data flow system which was a hybrid combination of the existing operational N-AWIPS data flow system and the OWSS DBNet. Dissemination of alerts were incorporated into the system when gridded model data and satellite imagery were made available. This system also provided Family of Services (DDS - Domestic Data Service and PPS - Public Product Service) data for display in NWX via LDM 4.1.42 to the LDM installed on the OWSS computers.

Some data, such as remotely-generated graphics files (meta files), were pushed to the OWSO from NCEP using ftp and were then sent to both the backup server and the OMWSO by a perl script called mirror. Since mirror compares the local and remote directories every 3 minutes using ftp's 'dir' command, it was modified to accept a list of files to reduce the amount of network traffic between the OWSO and the OMWSO and to overcome shortages of disk space.

☆ **DBNet proved to be a reliable and robust data communications solution during normal and contingency operations (such as a network outage). Once fully configured, DBNet ran with no human intervention on olympic1.**

☆ **Because of time constraints, the OWSS computers were not upgraded to DBNet version 2. The OWSS computers remained on DBNet version 1 which utilized the LDM as its data transport (version 2 includes a reliable DBNet end-to-end data**

transport). The performance of the LDM was exceptional during normal operating conditions but suffered reliability problems during contingency operations.

- ✘ **The Eta-10 model was run in a test mode prior to the Olympics, but the model was not tested at the time of the day planned for Olympic operations. Once the Olympics started, the model was reliably available in a timely fashion, but it introduced network contention problems between olympic1 and the OWSS IBM SP-2. Therefore, modifications in the notification between the Cray computers, olympic1 and the OWSS IBM SP-2 were re-prioritized. This improved the reliability of model data being received at the OWSO.**

- ✘ **Meta file dissemination from NCEP did not use DBNet and often proved to function unreliably causing meta files to arrive too late for operational use or not at all.**

Network security was provided by a Bastion Host, router filters (approximately 100 filters with filtering by host/service), and security logging (router logs and syslogs). The Bastion Host consisted of a 75 MHZ Pentium, dual network interface, Linux 1.3.79, and Trusted Information System's FWTK 1.3.

- ☆ **The security logs were monitored closely and provided a mechanism of detecting computer attacks by hackers. This function not only provided a detection system, but was important when resolving complex computer-related problems because problems could be resolved with the assurance that they were not the result of a computer hack.**

- ✘ **Prior to the Olympics, the Bastion Host provided security for the following services: ftp, telnet, LDM, DNS, mail, http, RAMSDIS transfers, xntpd, and secure portmapper. As the network load increased, a kernel bug surfaced ("socket packet overflow"), which resulted in "hung" ftp sessions. This problem was due to bugs with the development Linux kernel when used with the 3C590 network drivers. Use of the development kernel was necessary due to performance issues relating to the LDM (at the time, the released kernel did not adequately support mmap). As a result of these problems, and because of time constraints, most of the operational ftp was removed from the Bastion Host, as well as the LDM and RAMSDIS transfers. The availability of the Bastion Host did provide a contingency plan in case of computer attacks by hackers, in which case it would have been brought back on-line in its full configuration.**

In addition to supplying information to ACOG, two forms of communication were in place for distributing information to the VCCs; 1) fax - for watches and warnings and 2) Info '96 (see Fig. 3&4). English and French weather information was transmitted to the Info'96 system via a Point-to-Point dedicated 64 KB line. The line was connected directly to a PC in the OWSO operations area. ACOG polled a subdirectory in this PC every 10 seconds for new information which it automatically downloaded into Info'96. In the event of a failure of this dedicated line, ACOG could dial into the OWSS.

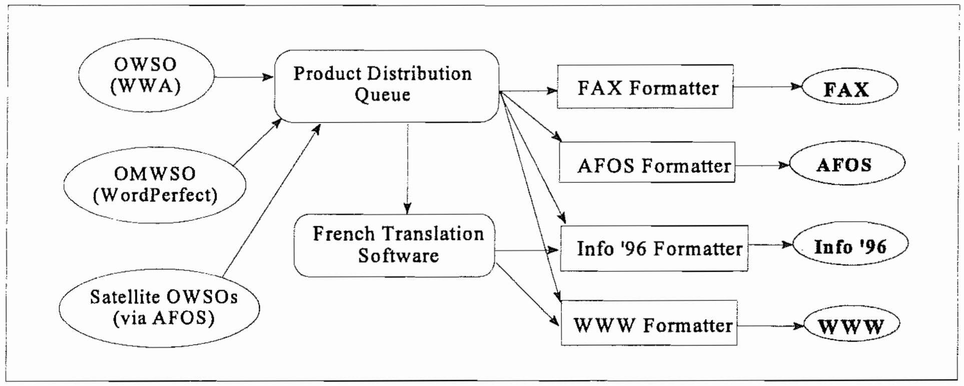


Fig. 3 Flow of Watch, Warning, and Statement products.

The OWSOs also provided information to the general public via a WWW homepage run by an IBM web server. Finally, data were supplied to the standard NWS product channels (NOAA Weather Wire Service and Family of Services) and NOAA Weather Radio.

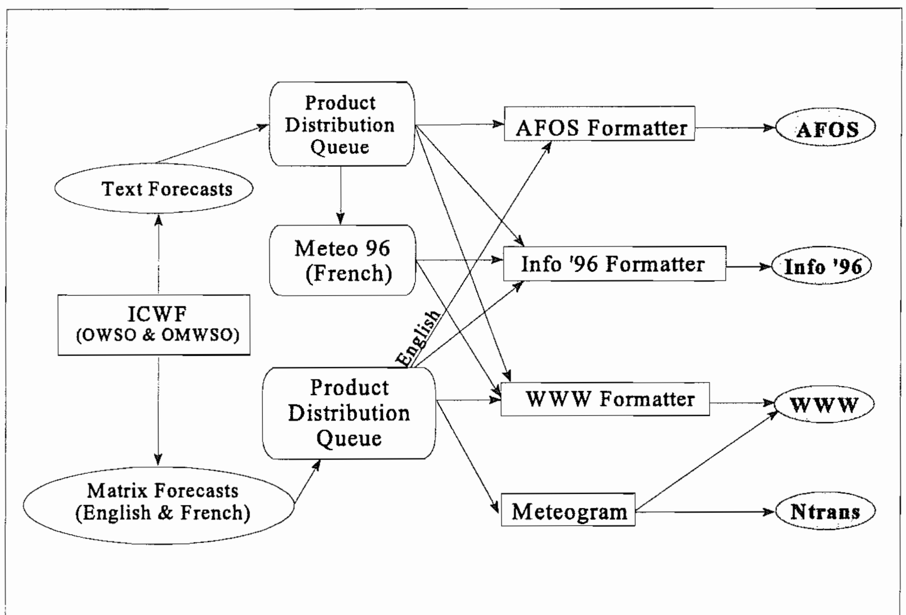


Fig. 4 Flow of forecast products.

With products being distributed to many different destinations, each requiring a different format, a product distribution spooler was developed to call the proper reformatters and archive the original product. The spooler keyed on information in the filename to determine the type of file, priority, and destination(s):

1. Products sent to AFOS were copied unchanged to an AFOS spooler that used TDL's 'afoscom' software.

2. Fax formatters split products up according to venue, added a header, and looked up the venue's fax number. A fax spooler was employed to feed four fax servers around the network in a round-robin fashion. A watch or warning could be faxed to a single venue in under 1.5 minutes.

3. All products destined for Info '96 were converted to ACOG format and copied to a directory that was polled by Info '96 using ftp.

4. If a product had to be translated to French, it was copied to a PC running Meteo96 translation software (Chandioux and Grimaila, 1997). After the translated product was checked and, if necessary, edited, Meteo96 forwarded it to the Info '96 directory.

5. Products destined for the web page were converted to HTML and ftp'd to the web site.

After all of the required actions were performed, the spooler archived the original file and removed it from the queue.

Because the Olympic competitions were held in several states, NWS offices in Miami, FL; Birmingham, AL; Melbourne, FL; and Washington DC also contributed watches, warnings and forecasts. Those products were received from AFOS via the LDM and were post-formatted to bring them in line with the locally-generated products. Post-formatting consisted of adding an ACOG header and inserting a venue cluster ID in the text. After the products were modified, they were queued for faxing and translation. The Meteo96 translation software converted the text to lower-case and added metric equivalents before passing it on to Info '96 and the translation queue for conversion to French.

☆ **The product distribution spooler provided an easy method by which to make modifications of where, when, and to whom the products were transmitted. Thus, if a new customer came on line, they were simply added to the database and the necessary products would be transmitted to them.**

☆ **With many end-users not having access to the NOAA Weather Wire Service, yet having critical needs for weather information, the WWW homepage provided an invaluable means by which to communicate non-time-critical information. Known users of the WWW Olympic weather information included military personnel, venue security personnel, state health agencies, The Centers for Disease Control, and The Weather Channel.**

✗ **ACOG requested that all faxes sent to the individual VCCs also be sent to ACOG headquarters, therefore, all of the headquarters' faxes were sent to one fax server to avoid having two or more servers calling the same number at the same time. This destroyed the balance of the fax distribution system and caused some fax**

servers to remain idle while others still had several faxes queued. Most of the technical support staff's time during the Games was spent balancing the distribution of faxes among idle servers and monitoring the faxes themselves to ensure they were successful. ***Faxing is not a viable means of sending warnings.***

There were four fax/modem lines to which the OWSS had access. Off-the-shelf software was acquired and configured to access these lines in a round-robin sequence when disseminating information to the VCCs. There were additional phone lines for mesonet data collection (3), ACOG and VCC coordination (3) and media interaction (2).

d. Data

Mesonetwork

The NWS installed 13 Campbell Scientific surface observing sensors at or near venue sites for the Olympic Games (Garza and Hoogenboom, 1997). These sensors along with sensors from the University of Georgia and the Georgia and South Carolina Forestry Commissions comprised a mesonetwork of 52 surface observing sensors. Temperature, relative humidity, precipitation, wind speed and wind direction data were collected every 15 minutes. The stations were polled via telephone by two PCS running IBM's OS/2 Warp. The collected data were reformatted to a database-ingest format and sent to a HP-755 for further processing and distribution.

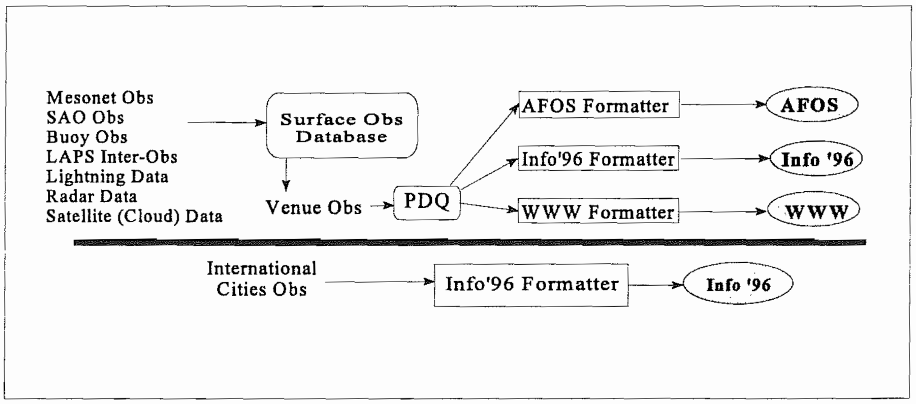


Fig. 5 Flow of observational data.

In all, surface data arrived in the OWSO from three sources. Each surface data source served a different function within the OWSO.

Source	Via	Serves
METARs	AFOS	LAPS and surface obs database
Mesonet collection	Modem	LAPS, surface obs database and WDSS
Family of Services	NCEP T1 line	N-AWIPS, GEMPAK, GARP

☆ **The mesonetwork was perceived by forecasters as crucial to the mesoscale forecasting tasks. Data collected from the mesonetwork improved the quality of the LAPS analyses which were used extensively during mesoscale forecasting**

routines. Forecasters were virtually unanimous in their opinion that 15-minute surface data collections were valuable in creating better forecasts and warnings, especially at such increased geographic density.

- ✘ **The quality of the data was a major concern. For example, the relative humidity measurements tended to drift with the temperature. Sitings of some of the sensors were poor (the only available location for the Lake Lanier sensor, for example, was on a narrow slip of grass between a large, asphalt parking lot and the lake.) Quality control procedures were put in place to minimize the effect of these sensor problems, but they could not completely correct some of the systematic errors.**

Satellite

The satellite data were acquired from either SPC (primary) or NESDIS (backup). The MICs of the OWSO and OMWSO were authorized to request rapid (7.5 minute) scans of the GOES-8 satellite. The decision on the need for rapid scans were made on a daily basis, usually during the morning coordination call with the OMWSO.

Special RAMSDIS satellite discussions were created by CIRA several times each day. These discussions were designed to assist in the interpretation of the high-resolution RAMSDIS images. The discussions were available on N-AWIPS.

- ☆ **The high-resolution satellite data (to 1 km on visible channel) was invaluable to forecast and warning operations.**

- ☆ **The satellite discussions from CIRA were particularly helpful, especially since the RAMSDIS technology was new to several of the forecasters.**

- ✘ **Although 7.5 minute scan rates were requested, there was no strong impression that such frequent scans had much advantage over the normal 15-minute scans. It is possible that 3-minute scans would have been more valuable.**

Air Quality

The sole source of air quality data was the Georgia Environmental Protection Department. These data were acquired via anonymous ftp from a special account at the Georgia Tech University. Data were collected from various GEPD sensors and assigned to Olympic venues

Lightning

Lightning data entered the OWSS network via a dedicated satellite downlink. The lightning information were only displayable in WDSS and, in a roundabout way, in the venue observations when cloud-to-ground lightning strikes occurred within 10 miles of a venue.

Radar

WDSS was connected to the Peachtree City WSR-88D RDA on Wideband 3. The Peachtree City (KFFC) and the Warner-Robins (KJGX) PUPs in the WFO were available, if necessary. The OMWSO WDSS was attached to the Charleston, SC, WSR-88D. The Savannah WSR-74C radar was available for backup.

NCEP Models

Twice-daily runs of the Eta model in three different configurations comprised the suite of runs. At 00Z and 12Z, the early Eta ran with forecasts to 48 hours, and covered the largest domain (all of North America) with a 48 km grid size at 38 levels in the vertical. Each early run was preceded by 12 hours of data assimilation (EDAS) using a 48 km / 38 level Eta model prediction with 3-hourly analysis updates using an OI scheme based on high-frequency data sources (profiler, ACARS, ASOS, GOES-8 moisture, VAD [WSR-88D] winds and hourly surface reports).

The second Eta model run was the new Eta-29 (a.k.a. meso-Eta). This system ran at 03Z and 15Z with forecasts to 33 hours. This run covered the contiguous 48 United States and substantial portions of Mexico and Canada, the adjacent oceans, all of the Gulf of Mexico and the northern Caribbean Sea. Horizontal resolution of the grid was 29 km with 50 levels in the vertical. Initial conditions were spun-up from a mini-EDAS and lateral boundary conditions were based on the current aviation run.

The third Eta model run was the Eta-10. This had been developed specifically in support of the Atlanta activities both in 1995 and 1996. The runs were being made through the generosity of Cray Research at their facility in Minnesota. The domain for this run was roughly a quarter of the Eta-29's domain and covered the eastern half of the United States, the Gulf of Mexico and western Atlantic. Vertical resolution had been increased to 60 levels and runs were made with horizontal resolutions at 15 km and 10 km in 1995 and 1996, respectively. The 1996 version was run non-hydrostatically. The Eta-10 ran as a 1-way nested system within the meso-Eta. A special analysis based on a 3-dimensional variational approach (3D-VAR) was used to allow the direct analysis of WSR-88D radial velocities together with surface mesonet data and the more conventional high-frequency data sources listed above.

Model output was tailored for the support of the Atlanta activities. High-resolution displays were available on-site using N-AWIPS. These comprise both horizontal and vertical renderings of the model predicted fields and derived quantities. Also, Eta model output has been interfaced with the ICWF system.

✗ **The lack of experience with the Eta-10 on the part of the forecasters, system administrators, developers and managers proved to be a major hindrance to the complete implementation and use of this model. While the Eta-29 arrived and was used routinely, the Eta-10's arrival was intermittent due to coding errors (model failure) on the CRAY, communications programming errors, system configuration problems, and/or simple miscommunication between NCEP and**

OWSO personnel. Nevertheless, most forecasters used the data when they arrived and found them to be quite good, although they had little experience with the model.

RAMS

The Regional Atmospheric Modeling System (RAMS, Snook, et al. 1997) was run at the OWSO on the 30-node IBM RS/6000 SP2. A nonhydrostatic mesoscale numerical model developed at Colorado State University, RAMS was initialized with operational surface and upper air analyses from LAPS with as little manipulation to the initial fields as possible.

The horizontal domain was equivalent to LAPS (i.e., 85 x 85 grid points with an 8 km resolution). The vertical grid was a stretched sigma-z coordinate system with a 300 m grid spacing nearest the ground, a stretch factor of 1.1, and a maximum grid spacing of 750 m. Hence, the model top was approximately 15.3 km above the surface. The vertical grid spacing was designed to maintain all the available resolution in the LAPS analyses while foregoing greater resolution to allow implementation in real time. Model topography was set equal to the LAPS terrain. The domain of the 8 km runs included all of GA, eastern AL, southern TN and most of SC. The 2 km resolution was run on a movable domain. The RAMS model was run each day every 3 hours from 06 UTC to 21 UTC. The model runs generally ran to 14 or 15 hours before the next model run would start.

A time-dependent lateral boundary condition was implemented to force the model variables toward forecast values derived from the operational Eta-29, Eta-10 or RUC models provided by NCEP. The 8 km RAMS required the LAPS surface analyses and the Eta-29 or Eta-10 as boundary conditions. The 2 km RAMS used the RUC for its boundary conditions. If none of these precursory fields were available, RAMS would not run. Output from this model was available in NTRANS, GARP and Visualization Data Explorer.

- ☆ **Forecasters felt that both Eta-10 and RAMS proved useful in increasing the quality of the final forecast product. Both models sought to simulate mesoscale phenomena and both did reasonably well. In general, however, the Eta-10 handled synoptically-forced situations very well while RAMS did much better on purely mesoscale phenomena (e.g., timing and location of convective initiation, timing and strength of the sea breeze, etc.).**

- ☆ **Having a mesoscale model (RAMS) that could be run on a frequency matching the mesoscale time scale had a significant positive impact on mesoscale forecasting operations. As opposed to the Eta-10, which gave 3-hourly output twice daily, the 8 km RAMS produced hourly output, with a new run available every three hours. Comparing output from sequential RAMS runs proved most effective in predicting how the mesoscale environment was changing. If the Eta-10, by comparison, missed its prediction, the next solution was not available for comparison until 12 hours later. This "run-on-demand" capability was among the greatest attributes of the RAMS.**

☆ **Of significant benefit to the Olympic Games forecasters was that runs of the RAMS were controlled entirely by them. Initialization time, location and resolution (8 km vs. 2 km) could all be determined "on-the-fly." Thus, forecasters could apply the model directly to the forecast problem of the day.**

Note: These findings are not an advocation of an SP2 in every WFO, but serious thought should be given to ways of allowing forecasters to control regional model runs - even if remotely to a centralized facility housing multiple, large capacity computers.

<u>Technology</u>

The four goals of the OWSS were accessibility, integration, intuitiveness and data portability (Rothfusz, et al. 1996a). The degree to which the OWSS succeeded is measured against these criteria.

*Accessibility:*Weather data of all kinds were readily accessible to forecasters at the OWSO and OMWSO, although internal communications speed at the OMWSO sometimes hindered the access. Forecasters desired no additional data types.

Integration: To a great degree this succeeded. With the exception of RAMSDIS and Meteo 96 which both were on stand-alone personal computers, all software and data were available on each HP workstation.

Color table conflict was a major obstacle to integration because most of the software packages use many colors in their display of information. The HP hardware chosen for use in the OWSS had only 8-bit graphics (256 colors). Thus, the number of available colors, for each of the software packages was limited. This situation was initially so bad that a forecaster was not able to examine numerical model information in N-AWIPS, and manipulate forecast numbers in the ICWF at the same time. To overcome this color conflict, each of the major software package developers was asked to help solve the problem. The solution was multi-faceted:

1. N-AWIPS was reconfigured at startup to allocate a selectable number of colors rather than all the potentially-needed colors. Originally, N-AWIPS allocated all the colors that would possibly be needed by any of it's applications at startup (33 for model viewing in NTRANS, 95 for satellite display, NSAT, and 20 for radar display). The reconfiguration allowed the user to determine the numbers of colors that would be allocated at start-up for each of these three applications and then allocate any additional needed colors when the application was invoked. For the OWSO and OMWSO, the default startup was set to allocate only 33 colors for NTRANS and allocate no colors for NSAT or the radar display portion of N-AWIPS. NSAT was used only as a backup to RAMSDIS and the WDSS system served as the radar display.
2. ICWF was reconfigured to take advantage of a second color map available on the HP 715/80 workstations equipped with HCRX graphics devices.

3. WDSS was reconfigured to use only the same colors that were commonly allocated for N-AWIPS and if it was unable to allocate all the needed colors, the color loss would take place in the least used product in the WDSS display package.
4. The HP Visual User Environment (VUE) was configured for low-color usage on each of the forecaster accounts.

Even with the above resolution, color conflicts were still a potential problem during operations. However, a "normal" routine of using the various software packages could be done without too much interference from color conflicts. Still, there were some combinations of software that would not run together. These were, for the most part, limited to "uncommon combinations of software" such as documenting a forecast from the previous day with WordPerfect while trying to issue a warning using WDSS and WWA. Some general rules were adopted to overcome most of the potential problems and forecasters were trained on how to overcome the potential problems.

Intuitiveness: Although hard to objectively determine, this goal appears to have been achieved. Forecasters commented that the system was generally intuitive and easy to learn. Most felt comfortable on the system after one week of experience.

Data Portability: Data created by the OWSO and OMWSO needed to be quickly disseminated directly to each venue, to Info'96, to the OWSO/OMWSO homepage, to NOAA Weather Wire Service (NWWS), and to NOAA Weather Radio (NWR). Info'96, the homepage and NWWS received information digitally. This worked well. Each venue, however, received bulletins via fax. While this was a direct approach, paper outages, busy signals, communications incompatibilities and other problems made it a less-reliable and less-desirable option.

The distribution medium with the most potential for effectiveness was Info'96. Although it suffered the plight of most prototypes, it was still best suited for communicating OWSS information because it was configured to present data in a manner matching the detail and resolution of the original OWSS data. For example, three-hourly forecast values from an OWSS-generated matrix were viewable either as a day-long time series or as clearly-labeled data on a sequence of pageable screens. The user-friendly interface of Info'96 was designed to match the highly-detailed weather information. Other media were less effective because they could not capitalize on the detail, resolution, and volume of the products. NWR, for example, could only deliver generalized versions of the detailed forecasts.

The OWSS's new technology brought increased precision and resolution, but without comparably-improved communication systems like a www homepage or Info'96, the benefits of the technology would not have been reaped fully.

Based on the goals mentioned above, the overall the performance of the OWSS was quite good. What is especially noteworthy is that it took less than two years to design and assemble a working system.

☆ **The entire OWSS was assembled and working within 18 months of its inception. This rapid implementation was achieved because several talented meteorologists/programmers who would use the software during the Games were either intimately involved in the development process, or were the developers themselves. These people were given the time, tools, software and freedom to create the OWSS in its final working state.**

6. Operations

a. Olympic Weather Support Office

Training

It is one thing to bring the world's best technology into an operational forecasting setting, it is an entirely different (and more difficult) issue to train forecasters to fully exploit the technology. Most forecasters had limited exposure to the state-of-the-art software available on the OWSS. Data interpretation and product preparation in NWS forecast offices are typically accomplished via a combination of PCS and AFOS. Issues not related to technology pose additional training challenges. For example, local geography, climatology, and the unique weather support needs of the Games had to be included as a part of the training.

Fifteen of the OWSO forecasters (plus the 6 alternates) were NWS employees from around the U.S., three were forecasters with the Canadian AES and one was with the Australian Bureau of Meteorology. Naturally, these forecasters all had varied backgrounds. Also, the time allotted for centralized training was limited. Since the forecasters hailed from the U.S., Australia and Canada, any extended centralized training program would have been cost-prohibitive. Thus, what centralized training could be accomplished had to be quick and effective.

1995 Training

For about six weeks in the summer of 1995, the Atlanta Committee for the Olympic Games (ACOG) hosted a series of international sport competitions known as the Atlanta Sports Festival '95. The competitions were held at most of the venues used in 1996, including an international sailing regatta near Savannah. This festival, commonly called the "test events," provided an opportunity to test technology and procedures slated for use during the 1996 Games. It was also an excellent opportunity to train forecasters. Thus, OMWSO and OWSO forecasters were each scheduled for one week of training in Georgia during the summer of 1995.

Prior to their arrival for training, forecasters were given a training video and a supplementary training binder called *The Forecaster's Guide*. The training video was created to familiarize forecasters with the OWSS and its component programs. Footage for the video was provided by several organizations assisting in the weather support. *The Forecaster's Guide* contained material supplementary to the video, including user's manuals, relevant technical articles, etc. Forecasters were required to view the video and read the material prior to receiving centralized training.

All primary and alternate OWSO forecasters received five days of training in Peachtree City. The training consisted of two to three hours of orientation, one day of classroom instruction and then four days of on-the-job-training (OJT) when forecasts and warnings were provided to the Atlanta Sports Festival '95. Forecasters were scheduled three at a time for five-day training tours. This spread the training over six weeks so that weather support could be provided during the Festival.

In the classroom sessions, training was limited to the basics (e.g., the "knobology") of the various OWSS component software. Most of the operational experience was expected to be gained during OJT.

After OWSO forecasters received their one-day classroom training, each spent one day "shadowing" a forecaster from the preceding crew before assuming support responsibilities on their own for three days. On the last day of a forecaster's training, he/she was shadowed by a forecaster from the next crew. Scheduling this overlap proved particularly effective in helping trainees learn the technology quickly. As a "shadow forecaster," they could learn from the mistakes of their predecessors who learned from their predecessors, and so on. The SOO and MIC frequently monitored these interactions to ensure that erroneous information would not be propagated.

To keep their newly-acquired skills tuned after training ended, a www homepage was developed. The homepage provided information on changes and upgrades to the OWSS, results of interesting cases from 1995, results of studies done especially for the Olympic weather support (e.g., lightning climatology), and examples of new data types that would be available in 1996.

1996 Training

In early June of 1996, updated material for *The Forecaster's Guide* was sent to all OWSO forecasters. The forecasters arrived on June 27 for three days of re-orientation. A Station Duty Manual developed for the OWSO served as training material for operational issues on the first day. Hands-on "knobology" training and tours of several venues were offered on the remaining two days. Although the tours were voluntary, all forecasters took a tour. From July 1 - 5, forecasters operated in a "silent forecast" mode, creating all products, but transmitting them to no one. On July 6, full-scale operations support began.

☆ **All the training provided was essential and effective, including the training/dry run one year ahead of time. Although forecasters were away from the office longer than they and their supervisors may have liked, the extra time ensured smooth operations during the Games. Several forecasters commented favorably on the benefits of the silent forecasting period. Most were comfortable on the technology within one week. All forecasters but one said they were adequately trained.**

☆ **The most utilized training source was *The Forecaster's Guide*. Several forecasters referred to this (and the Station Duty Manual) regularly.**

Period of Operations

The Olympic Villages opened July 6, and full-scale OWSO support began. Info'96 was scheduled to go operational on that date. Unfortunately, it did not come on line until July 12. Support continued through August 5 (the day after Closing Ceremonies). Since Info'96 was operational through August 8, and because several venues had requested support during the draw-down phase of the Olympics, the Paralympic forecasters arrived on August 6 to provide this support and receive training for the Paralympics at the same time.

✘ **Organizers of similar support projects in the future should consider providing support for a few days following the end of the events. Staffing should be cut back corresponding to the diminished workload as the sporting activities are completed. This includes reducing staffing prior to the conclusion of the Games, as there are fewer and fewer events scheduled for the final days.**

Operational Practices

Staffing and Shift Responsibilities

Staffing levels in the OWSO were atypical for standard NWS operations, ranging from one person in the early morning to eight during the prime period for thunderstorms. At peak staffing, OWSO positions were: Long-term forecaster (1), radar/warning forecaster (2), mesoanalyst (2), media liaison (1), operations assistant (1), translator (1).

OWSO forecasters worked staggered, ten-hour shifts. Translators and technical support staff, however, worked eight-hour shifts. In the list below, the first two numbers in the shift identifier indicate the shift's starting time. The OWSO shifts were:

Shift	Hours	General Duty Description
00 Fcst	0000 - 1000	Day 1 and 2 Forecaster
09 Fcst	0900 - 1900	Day 1 and 2 Forecaster
06 Assist	0600 - 1600	Operations Assistant
12 Meso/S	1200 - 2200	Mesoanalysis - South Venues
12 Meso/N	1200 - 2200	Mesoanalysis - North Venues
14 Meso/S	1400 - 2400	Mesoanalysis - South Venues
14 Meso/N	1400 - 2400	Mesoanalysis - North Venues
04 Comms	0400 - 1400	Communications
14 Comms	1400 - 2400	Communications
12 Floater	1200 - 2200	Peak Operations Day Assistant (one per week)
05 Xlate	0500 - 1300	Translation/Extended Forecast
13 Xlate	1300 - 2100	Translation/Extended Forecast
04 Tech	0400 - 1200	Technical Support
10 Tech	1000 - 1800	Technical Support
16 Tech	1600 - 2400	Technical Support
12 Tech	1200 - 2000	Technical Support

☆ **Most forecasters liked the ten-hour shifts. Having three days off (and sometimes more) per week allowed better opportunities to "take in the sites." The 10-hour midnight shift was deemed generally tolerable, partly because the person was assigned mentally invigorating tasks during the last few hours.**

Routine, long-term forecasts were scheduled for issuance four times per day. Each of these routine issuances, and updates when needed, were assigned to the 00 Fcst and 09 Fcst shifts.

Venue-specific watches and warnings were issued as needed and every forecaster was asked to be ready to assume watch/warning responsibilities regardless of the shift he/she was working. If only one forecaster was on duty when weather threatened Olympic venues, that forecaster was required to determine whether additional assistance was warranted and call in assistance, if needed. If two or more forecasters were on duty, any forecaster *not* assigned to the 00 Fcst or 09 Fcst shift took the lead role for watches and warnings. In some cases, it was necessary to postpone issuance of routine forecast products to ensure that adequate watches, warnings and updates were issued.

Two, two-person teams dedicated to mesoscale forecasts and warnings were scheduled daily from 1400 - 2200 EDT. Each team was comprised of one person doing mesoanalyses while the other person interpreted WDSS and issued warnings. Both members of each team were responsible for making warning decisions. Each team was responsible for either North or South venues as shown below.

North Team Venues	South Team Venues
Ocoee	Olympic Ring
Lake Lanier	Atlanta Beach
Athens	Wolf Creek
Stone Mountain	Columbus Golden Park
GIHP	

The watch/warning forecasters monitored WDSS. Together, the mesoanalysts from each team jointly used RAMSDIS, LAPS, N-AWIPS, etc. to assist in creating their respective mesoanalyses and mesoscale forecasts (mesocasts).

☆ **The teamwork between the mesoanalyst and the radar interpreter significantly improved the overall quality of the support and, despite the integration of software on the workstations so that one person could theoretically do it all, two people were still required to do the job right, i.e., so that the best science could be applied to the warning operations.**

✗ **Although tasked with mesoanalyses, the mesoanalysts frequently had to serve as warning text preparers due to the increased workload during active weather.**

A shift devoted to handling miscellaneous operational issues was scheduled each day from 6:00 a.m. to 4:00 p.m. This 06 Assist shift was responsible for answering incoming phone calls, retrieving information for the mesoanalysts, creating and reading NWR scripts, coordinating severe weather warnings with NWSFOs and any other miscellaneous duties that presented themselves in operations. Like the daily 06 Assist shift, the 12 Floater shift provided operational assistance, but only on one day each week - the day with the most Olympic activities scheduled for that week.

Each day, there were two shifts devoted to communications with external users. Among other duties, the 04 Comms and 14 Comms shifts were responsible for preparing material and computer images for the media, assisting the MIC in providing media briefings, and/or conducting the briefings if the MIC was unavailable. Preparation of computer graphics involved creating animated

3-D images using IBM's Visualization Data Explorer™ (DX) software. Much of this person's time was spent in the Media Room. The 04 Comms shift had the additional responsibility of briefing ACOG officials, and some foreign media each morning.

Translation shifts were staffed by forecasters from the Canadian AES. While their primary responsibility was to edit the output from Meteo 96 (French translation software), they also provided forecast and warning support at various times.

- ✘ **Although the Meteo 96 translation software helped considerably, the translation workload was such that the AES meteorologist rarely had opportunities to become fully-immersed in meteorological operations. This was a waste of talent. Future activities requiring translation should consider the use of translators (versus bilingual meteorologists). That said, John Chandioux Consultants (developers of Meteo 96), who urged use of trained translators, reversed their position when they saw benefit in having a bilingual *meteorologist* translate meteorological text because meteorologists understand the contexts better than would a layperson. Nevertheless, it is our recommendation that trained translators be used in future endeavors.**

Members of the core OWSO development staff worked the technical support shifts. These shifts covered the period from 0400 to 2400 daily. In addition, the Forecast Systems Laboratory made one person available to assist in running and interpreting the RAMS and LAPS data.

- ✘ **Even after accounting for the uniqueness of the OWSS, it is still clear that maintaining the underlying system integrity, data flow, data storage, communications, etc. of an AWIPS-like system requires extensive attention by a system administrator. At the OWSO, 100% of the systems administrator's 40-hour work week was dedicated to maintaining system integrity.**

Except for the period between midnight and 4 a.m., there were always two or more forecasters on shift at a time. No forecaster was designated as a "lead" forecaster. Thus, operational decisions which historically may have required the command decision of a shift supervisor were made as a team. Nevertheless, for shift operation situations which impacted the NWSFO, the Lead Forecaster of the NWSFO had supervisory authority.

Mesocasts

Mesoscale forecasts or "mesocasts" were prepared by the mesoanalysts every two hours from 6 a.m. until noon and then hourly until 9:00 p.m. Although this product was not distributed externally, it was used as a tool for constantly and consistently monitoring mesoscale phenomena.

A special form with three base maps was developed for this purpose (see example in Appendix B.) These maps, known as "Key Mesoscale Features" maps, documented for an extended period those areas which might have become conducive to convective initiation. Peripheries of areas where fog dissipated in the morning, rain fell the previous day, or clouds were prevalent were possible locations for convective initiation. These, along with more obvious features such as wind shifts and/or thermal and moisture gradients, were indicated on the form.

The "First Echo and One-Hour Precip Mesocast" map was used to predict the onset and subsequent movement of convection/precipitation. The location and time of first echoes (> 20 dBz) were predicted by identifying a block of four counties in which they were expected to form and labeling the expected initiation time. New first echoes were forecast even though precipitation may have been taking place in another area.

Finally, the "One-Hour Non-Precip Mesocast" map was used to show the forecast position of key weather features important to Olympic venues.

☆ **The mesocast form became an integral part of the mesoscale forecast operations. It helped forecasters track features and focus their thoughts on possible mesoscale forcing mechanisms. It is recommended that a similar device for tracking mesoscale features - even for long periods of time - be devised for NWS operations. Such a device could be in paper format, but tools (software) that integrate data and provide guidance on convective initiation are what are really needed.**

Media Interactions

Media interactions were a significant part of OWSO activities. A Media Room was established in the NWSFO Conference Room. The Media Room contained an HP workstation, an IBM workstation (for displaying DX images), a 37" NEC monitor connected to each of the workstations, a white board for status messages, a desk for the Public Affairs Officer (PAO), extra phone lines, a fax machine, and ample room for media interviews. The PAO played a key role in streamlining the media interactions and facilitated numerous external contacts. Calls from the media were referred to the PAO, the MIC or the person working a Comms shift.

At times, OWSO staff were asked to give interviews or be on camera as backdrops to other interviews. For example, MS-NBC placed a robotic camera (no audio) in the OWSO operations area as a "cut-in" tool for interviews. Daily weather briefings and interviews were made available to the media, although very few reporters were interested in the weather briefings. A Weather Status Board was updated daily to show statistics from the previous day and forecast information for the coming day.

☆ **These media-related operations were crucial to ensuring smooth interaction with the media. Until the Centennial Park bombing occurred, media activity was intense, averaging eight contacts per day. Without the PAO and the Comms shift forecasters, the workload would have been overwhelming for the MIC and the OWSO staff. Future Olympic weather support activities should include a PAO.**

Verification

Verification of the quality of a forecast was obtained by examining verification meteograms displayable in N-AWIPS. These meteograms compared the observed parameters (venue obs) vs. forecast parameters in the forecast matrices. In addition, these meteograms were printed out at the end of the day as an aid in evaluating forecast quality.

A Watch/Warning and Verification Log was maintained by the mesoanalysts. A watch or warning verified if the phenomenon was confirmed (or was likely) to have occurred at the venue site. Warnings for multiple phenomena were verified for each phenomenon at each venue/cluster. For example, a Lightning and Rain warning issued for Ocoee River constituted two warnings. Lightning alone would only verify the lightning part of the warning. Rain (of any amount) would have had to have been verified separately.

The forecasters were encouraged to use all available resources in determining whether or not the watch/warning verified. This may have included calling the VCC for verification, and on some occasions, warnings were verified by watching the event on TV. Overall probability of detection (POD), false alarm ratio (FAR) and Critical Skills Index (CSI) statistics were calculated for each day and for a running total.

☆ **The real-time feedback provided by automated meteograms comparing observations with forecasts was extremely helpful. Such tools helped forecasters decide whether updates should be issued, understand a weather situation as it was happening, and better forecast localized phenomena in the future.**

Forecasters' Journal

To help OWSO forecasters gain experience forecasting mesoscale phenomena in the Southeast as quickly as possible, each forecaster was required to make entries into the *Forecasters' Journal* - a WordPerfect file containing the "operational diaries" of the forecasters. The entries were divided into four sections:

Meteorological Overview: In this section, the forecaster described the synoptic and mesoscale conditions, as well as the forecast problem(s) of the day in one sentence for each part. For example,

> Synoptic setting: Bermuda high to the northeast.
> Mesoscale setting: Southeast flow with outflow boundaries in Georgia.
> Problem of the Day: Location of convection in late afternoon.

Forecast Rationale: In this section, forecasters described the reasoning behind their forecasts as thoroughly, yet concisely, as possible.

Verification: This section was completed on the day following the preceding forecast. It was used as a means for forecasters to learn from each others' successful and missed forecasts. The descriptions in this section were to include the following categories: "Things that were well forecast" and "Things that could have been better forecast." Emphasis was placed on which forecast tools performed well or poorly in the situation.

Notes and Comments: Comments by the forecasters on ways to improve operations, software, hardware, etc. were included in this section. Notes on operationally-related discoveries, concerns, problems, etc. were also included.

The entries in this journal served as a reference and learning tool. More significantly, *Journal* entries formed the basis for entries into Coach.

Intra-office and Interoffice Discussions

Approximately 4:00 a.m. each day, the Senior Duty Meteorologist from the NCEP Heavy Precipitation Branch called the OWSO to coordinate on forecast problems for the day. The NWSFO forecasters often participated in this call. Later in the morning (about 6:30 a.m.), the OWSO forecasters initiated a call to the OMWSO to discuss forecast concerns, the need for rapid satellite scans, and changes in the location/time of the RAMS 2 km run.

At 9:45 am each day, OWSO, NWSFO and RFC forecasters engaged in a short weather discussion in the NWSFO operations area. Although the NWSFO Lead Forecaster was responsible for initiating the discussion, all forecasters were expected to discuss their thoughts about the day's weather situation. Emphasis was placed on discussing the NWSFO forecast problem of the day and how it related to the OWSO forecast problem of the day. Each afternoon at 12:45, the 09 Fcst shift led a briefing of the day's forecast concerns. Decisions on the need for supplemental RAMS runs were made at this time.

Products and Services

Issuance Schedule

Product	Routine Issuance Times	AFOS PIL
Surface Observations	Every 15 minutes (automated).	ATLOSOOLY
Today's Forecast Matrix	5:00 am, 12:00 pm, 5:00 pm, 12:00 am*	ATLTDMOLY
Today's Forecast Text	5:00 am, 12:00 pm, 5:00 pm, 12:00 am*	ATLTDTOLY
Tomorrow's Forecast Matrix	6:00 am, 6:00 pm, 12:00 am*	ATLTMMOLY
Tomorrow's Forecast Text	6:00 am, 6:00 pm, 12:00 am*	ATLTMTOLY
Day 3-5 Forecast Matrix	11:00 am, 12:00 am*	ATLEXMOLY
Day 3-5 Forecast Text	11:00 am, 12:00 am*	ATLEXTOLY
Forecast Summary	5:10 am, 12 pm, 5:10 pm	ATLOWSOLY

*As a result of insufficient staffing among the translators, products issued at midnight were created between 8:00 and 9:00 p.m., translated at that time, and stored for the midnight issuance. Any product created on ICWF after 8:00 p.m. automatically got "shuffled" forward by one day for the midnight issuance.

All products generated by the OWSO were transmitted to Family of Services, AFOS and the www homepage of the OWSO. Info'96 received all products except the Forecast Summary.

French language versions of the products shown in the preceding table were sent only to Info '96. The ICWF generated French language matrices.

OWSO Forecast Products

Forecasts for the present day (Today) and the next day (Tomorrow) were issued in both matrix and narrative text formats. Both formats had higher temporal resolution than forecasts normally produced by NWS offices. The matrix format had 3-hourly resolution, while the narrative text format had six-hourly resolution. Both formats were generated by the ICWF.

An example of the matrix format as it is generated by ICWF is shown in the box below.

```
/1 OLYMPIC RING VENUES
EST                 ,00  ,03  ,06  ,09  ,12  ,15  ,18  ,21  ,00
POT 3HR             ,00  ,00  ,00  ,00  ,00  ,00  ,00  ,00  ,00
POP 3HR             ,00  ,00  ,00  ,00  ,00  ,00  ,00  ,00  ,00
MN(°F)              ,42
MN(°C)              ,6
MX(°F)              ,63
MX(°C)              ,17
TEMP(°F)            ,44  ,44  ,48  ,56  ,60  ,58  ,53  ,50  ,47
TEMP(°C)            ,7   ,7   ,9   ,13  ,16  ,14  ,12  ,10  ,8
DEWPT(°F)           ,30  ,32  ,36  ,39  ,41  ,42  ,41  ,40  ,39
DEWPT(°C)           ,-1  ,0   ,2   ,4   ,5   ,6   ,5   ,4   ,4
RH                  ,57  ,61  ,62  ,54  ,48  ,59  ,62  ,66  ,76
HEAT INDX °F        ,    ,    ,    ,    ,    ,    ,    ,    ,
HEAT INDX °C        ,    ,    ,    ,    ,    ,    ,    ,    ,
WIND DIR            ,S   ,S   ,S   ,SW  ,SW  ,SW  ,W   ,W   ,W
WIND SPD MPH        ,5   ,5   ,10  ,15  ,18  ,10  ,8   ,8   ,7
WIND SPD KTS        ,4   ,4   ,9   ,13  ,16  ,9   ,7   ,7   ,6
WIND SPD KPH        ,8   ,8   ,16  ,24  ,29  ,16  ,13  ,13  ,11
WIND GST MPH        ,8   ,8   ,15  ,23  ,27  ,15  ,12  ,12  ,11
WIND GST KTS        ,7   ,7   ,13  ,20  ,23  ,13  ,10  ,10  ,10
WIND GST KPH        ,13  ,13  ,24  ,37  ,43  ,24  ,19  ,19  ,18
CLOUDS              ,BK  ,BK  ,BK  ,BK  ,BK  ,BK  ,BK  ,BK  ,CL
SIG WX 1            ,00  ,00  ,00  ,00  ,00  ,00  ,00  ,00  ,00
SIG WX 2            ,00  ,00  ,00  ,00  ,00  ,00  ,00  ,00  ,00
UV INDEX            ,    ,    ,    ,1   ,3   ,6   ,3   ,1   ,
WAVE HGHT FT        ,    ,    ,    ,    ,    ,    ,    ,    ,
WAVE HGHT M         ,    ,    ,    ,    ,    ,    ,    ,    ,
WAVE DIR            ,    ,    ,    ,    ,    ,    ,    ,    ,
WAVE PERIOD         ,    ,    ,    ,    ,    ,    ,    ,    ,
CRNT SPD KTS        ,    ,    ,    ,    ,    ,    ,    ,    ,
CRNT SPD MPS        ,    ,    ,    ,    ,    ,    ,    ,    ,
```

Forecast Matrix

The columns of the matrix corresponded to valid times of the parameters with the exception of PoP and PoT, which referred to the 3-hour period *starting* at the valid time.

The parameters included in the forecast matrix were:

POT 3HR	Probability of Thunder for the subsequent 3-hour period.
POP 3HR	Probability of Precipitation for the subsequent 3-hour period.
MN(°F)	Minimum Temperature (°F) for the 24-hour period from midnight to midnight.
MN(°C)	Minimum Temperature (°C) for the 24-hour period from midnight to midnight.
MX(°F)	Maximum Temperature (°F) for the 24-hour period from midnight to midnight.
MX(°C)	Maximum Temperature (°C) for the 24-hour period from midnight to midnight.
TEMP(°F)	Temperature (°F) at the three-hour interval.
TEMP(°C)	Temperature (°C) at the three-hour interval.
DEWPT(°F)	Dewpoint temperature (°F) at the three-hour interval.
DEWPT(°C)	Dewpoint temperature (°C) at the three-hour interval.
RH	Relative humidity (%) at the three-hour interval.
HEAT INDX °F	Heat Index (°F) at the three-hour interval.
HEAT INDX °C	Heat Index (°C) at the three-hour interval.
WIND DIR	Wind direction (map directions) at the three-hour interval.
WIND SPD MPH	Wind speed (mph) at the three-hour interval.
WIND SPD KTS	Wind speed (knots) at the three-hour interval.
WIND SPD KPH	Wind speed (kilometers per hour) at the three-hour interval.
WIND GST MPH	Wind gust (mph) at the three-hour interval.
WIND GST KTS	Wind gust (knots) at the three-hour interval.
WIND GST KPH	Wind gust (kilometers per hour) at the three-hour interval.
CLOUDS	Cloud cover at the three-hour interval. (see comment below)
SIG WX 1	Predominate significant weather at the three-hour interval. (see codes below)
SIG WX 2	Secondary significant weather at the three-hour interval. (see codes below)
UV INDEX	Ultraviolet Index at the three-hour interval.
WAVE HGHT FT	Wave height (half feet) at three hour interval (OMWSO only)
WAVE HGHT M	Wave height (meters) at three hour interval (OMWSO only)
WAVE DIR	Wave direction (degrees) at three hour interval (OMWSO only)
WAVE PERIOD	Wave period (seconds) at three hour interval (OMWSO only)
CRNT SPD KTS	Ocean current speed (knots) at three hour interval (OMWSO only)
CRNT SPD MPS	Ocean current speed (m/s) at three hour interval (OMWSO only)

Cloud codes of OV, BK, SC and CL corresponded to overcast (cloudy), broken (mostly cloudy), scattered (partly cloudy) and clear, respectively.

Significant weather codes (SIG WX) were:

Code	Weather
<blank>	No Significant Weather
W	Windy
F-	Light Fog
F	Fog
F+	Dense Fog
R-	Light Rain
R	Rain
R+	Heavy Rain
T	Thunderstorm (with lightning)
T+	Severe Thunderstorm

The ICWF software also created the narrative text format product in 6-hourly blocks. A sample of the format for Tomorrow's Forecast Text (TMT) is shown at right.

Note that temperature and wind speed values are given in both English and metric units. The ICWF software automatically generated dual units for the narrative version of the forecast and the matrix version shown previously.

Like the forecasts for Today and Tomorrow, the 3-5 day forecast was created in matrix and narrative text formats. The Day 3-5 forecast product, however, was more general and had less temporal resolution than the Today/Tomorrow forecasts. Sample formats of the matrix and narrative text are shown below.

```
/1 Olympic Ring

.Midnight to 6:00 am... A 50 percent
chance of thunderstorms.  Low
near 66°F (19°C).  Wind from the
southwest 5 to 10 mph (8 to 16 kph).

6:00 am to Noon... A 30 percent
chance of thunderstorms.
Temperatures rising from 67 to 75°F
(19 to 24°C).  Wind from the
southwest 5 to 10 mph (8 to 16 kph).

.Noon to 6:00 pm... A 50 percent
chance of thunderstorms.  High near
80°F (27°C).  Wind from the west 10
to 20 mph (16 to 32 kph).

.6:00 pm to Midnight... A chance of
thunderstorms.  Temperatures
falling from 75 to 63°F (24 to 17°C).
$$
```

Forecast Narrative

DAY	05Aug1996	06Aug1996	07Aug1996
MAX TEMP°F	100	98	80
MAX TEMP°C	39	38	26
MIN TEMP°F	75	68	68
MIN TEMP°C	22	20	20
POP	20	0	30
SKY COND	SC	SC	OV

Extended Forecast Matrix

```
.Saturday... Partly cloudy, hot and humid with a 20 percent chance of
thunderstorms. High 100°F (38°C). Low 75°F (24°C). South wind 15 mph (24
kph).
.Sunday... Continued hot with a high of 98°F (37°C).  Low of 68°F (20°C).
West wind 10 mph (16 kph).
.Monday... Cloudy and cooler.  High of 80°F (27°C).  Low of 68°F (20°C). A
30 percent chance of rain. Northeast wind 10 mph (16 kph).
```

Extended Forecast Narrative

Although Columbus, Georgia and the Ocoee River were in the forecast areas of NWSFOs Birmingham and Memphis, respectively, the detailed forecasts for these venues were issued by the OWSO, using the zone forecast product from Birmingham and Memphis as the basis for the forecast.

- ✘ **Although the NWS uses heat index as its measure of apparent temperature, the sporting industry uses wet-bulb globe temperature (WBGT). Future support for sporting events should include the WBGT as a measured and forecast parameter.**

- ☆ **The narrative text format divided into six-hour segments gave customers a clearer picture of what to expect at certain times of the day. Olympic officials (and possibly the general public) made daily plans by six-hour periods. Thus, these new formats provided more valuable information than the standard "high temperature today" format because they more closely matched the customers' needs.**

- ☆ **The matrix format forecasts were also well-received by customers and forecasters alike, especially since they provided a level of detail unavailable in the narrative text formats. Several venue activity planners commented positively on the value of this format.**

- ✘ **Presumably due to the novelty of the matrix format, few media outlets used this product. It was hoped that time series diagrams, which could be easily generated from these matrices, would be created by the media. In fact, several print media expressed interest in creating time series graphics, but none followed through.**

- ✘ **Although mesonetwork sensors were installed well before the Games at many of the venues, climatologies were not completed in adequate fashion for forecasters to utilize them in their forecasting routines. As a result, some localized phenomena were not known and were forecast poorly. Mean absolute errors for minimum and maximum temperatures at venues ranged from 1.5° to 3.5° F. It is felt that local climate studies for the venues would have improved these scores.**

Satellite OWSO Forecasts

The Satellite OWSOs (Birmingham, Sterling, Miami and Melbourne) provided forecasts for each of their respective satellite venues. These forecasts were in narrative text format only (no matrices). The three forecast products issued for the Olympic Games were similar to those issued by the OWSO and OMWSO, i.e., Today, Tomorrow and Day 3-5.

Birmingham, Melbourne and Miami OWSOs reformatted their standard forecast products and transmitted them under the AFOS PILs shown above. Software developed by the OWSO Systems Administrator automatically extracted from Sterling's EOL product the forecast information for the RFK venue, reformatted it and then sent it to AFOS, the homepage, Info'96 and the appropriate VCC (via fax).

Forecast Summary

Following each routine issuance of the Today's Forecasts, a general overview of the meteorological conditions forecast for all venues was issued. A template for this product allowed the forecaster to fill in only the relevant information. The Summary was divided into the following four sections.

Watches and Warnings in Effect... This section was automatically updated each time the template script was called. The list of valid warnings was obtained from the WWA database.

Forecast Summary for Today... This section was edited by the forecaster, as needed, because it always showed the summary issued by the previous forecaster.

Specific Weather Threats for Each Venue Today... Forecasters wrote a brief sentence to describe any significant weather expected for the remainder of the day at each venue cluster.

Short-Term Forecast... The "Summary" program automatically appended the last Short-Term Forecast (NOW) issued by the NWSFO.

The audience of this product included high-level Olympic officials (including the President of the IOC); the Centers for Disease Control; non-ACOG security and law enforcement officials; officials and athletes at training facilities removed from the standard venues; the military; and the media. The purpose of the product was to summarize the weather conditions expected during the earliest six to twelve hours, with special emphasis on those venues expected to be impacted by significant weather. Info'96 did not receive this statement.

✘ **The Forecast Summary was more popular than anticipated. Although the information customers needed was available in highly-detailed formats, several customers needed generalized, "Executive Summary" products. This was not anticipated adequately prior to the Games, so the Forecast Summary was created and modified several times during the support. In hindsight, a single, widely-distributed "forecast overview" product should have been developed at the outset.**

Surface Observations

All mesonet and SAO data were ingested by LAPS which performed quality control of the data, analyzed them and then created an interpolated observation, or "interob," for each supported venue. This was done every 15 minutes.

There was a twofold purpose in creating interobs. First, ACOG requested observations at each of the 36 Olympic venues. Cost and land availability precluded the installation of weather sensors at each venue, so the idea of "manufacturing" an observation for each site was conceived.

The second reason for creating an interob was to serve as a means for real-time quality control of the mesonetwork data. Due to the variety of sensors accessed, there was concern over the quality of the data. Interobs were supposed to reduce these effects because LAPS analyses incorporated data from ASOS and other higher-quality sensors. Admittedly, a bias from the lower-end sensors would always exist.

The final surface observations (or venue observations) reported for each supported venue were generated in a unique fashion. A database created by the OWSO Systems Administrator served as the collection point for all observational data, including LAPS inter-obs, lightning, radar, air quality, etc. The database assigned primary, secondary and tertiary observation sites to each venue so that, if the primary observation was missing, the secondary site automatically filled in the missing data. LAPS interobs were the primary observations for every venue, with nearest-neighbor mesonet or SAO sites serving as backups. The purpose of the database included:

1. Generating final surface observations for each venue;
2. Reformatting the data for various related applications (e.g., meteograms);
3. Organizing mesonet observations, since they could arrive late due to missed phone calls.

Supplemental data not available from the LAPS interobs (e.g., lightning and significant weather) were obtained from alternate sources, entered in the database, and then combined with the LAPS inter-obs to form the complete and final venue observation. For example, lightning data were used to indicate thunder at a venue when a cloud-to-ground strike was detected within 10 statute miles of the venue. Also, if WDSS detected a 40 dBz echo near or over the venue, it sent a message to the observation database that rain was occurring at the venue. Once collected in the database, these data were reformatted and transmitted to AFOS, Info'96 and the homepage.

☆ **Interobs were typically representative of the meteorological situation during uniform or linear weather conditions and were shown to be a practical concept during the Olympics.**

✘ **Interobs were not good at handling situations in which localized phenomena occurred. Nocturnal radiational cooling, for example, often resulted in localized minimum temperatures well below those of the surrounding area. LAPS, because of its bicubic spline analysis, was unable to resolve such localized features and the resulting interob minimum temperature for that venue was over-smoothed. Consequently, this practice was abandoned for calculating temperatures, and the LAPS (interob) temperature was replaced by the temperature from the nearest neighboring mesonetwork site. While this removed the quality control utility of the LAPS analysis, the reliability of the temperature sensors was sufficient to deem this a better (i.e., more representative) option.**

International Data

International surface observations were acquired from appropriate collectives and METARs on AFOS, and then automatically reformatted and transmitted to Info'96.

✘ **Organizers of similar support projects in the future should anticipate interest in international weather data. For several reasons, the NWS could not produce international forecasts for display on Info'96 (although ACOG requested the data). Only observations could be supplied. Data for cities bidding on future Olympic Games (winter or summer) were deemed especially important to avoid embarrassment of the officials from those cities. This was an unexpected requirement for the 1996 Olympics.**

Watches, Warnings and Updates

All OWSO watches, warnings and updates were issued with WWA. Any standard NWS watches and warnings (e.g., severe weather, tornado and flash flood) were issued by the NWSFOs or national centers which had watch/warning responsibility for their respective areas. WWA was configured to re-issue these products and it was the responsibility of the OWSO forecasters to monitor NWSFO, NHC and SPC activities for their original issuance.

In addition to the standard products, a variety of specialized watches and warnings were issued. As in all NWS watches and warnings, details such as time, location, duration and cause of the threatening phenomenon were included in the body of the product.

WWA would automatically include information relating to the nature of the watch, warning or update statement. Forecasters, however, wrote a discussion section in each product type. Forecasters were required to include the following information in all discussion sections:

1. The expected time of onset of the phenomenon.
2. How intense the phenomenon is expected to be.
3. When the phenomenon is expected to end.

When warnings had been issued, or when activity for which a watch had been issued was close to exceeding warning criteria, follow- up Weather Status Statements were issued frequently. Support activities for ACOG prior to the Olympics demonstrated that statements issued as frequently as every 10 minutes were necessary when a warning for a convective phenomenon was in effect. Fortunately, WWA had a feature that advised forecasters when follow up statements were due.

Although Columbus, Georgia and the Ocoee River were in the county warning areas of NWSFO Birmingham and NWSO Morristown, respectively, the watches, warnings and statements for these venues were issued by the OWSO. Close coordination between these offices was necessary, especially during convective weather events.

The following table summarizes the variety of venue-specific watches and warnings that could have been issued. These watches/warnings were combined as the need arose (e.g., Watch for Hail, Lighting and Winds > 30 mph).

Watch/Warning	Criterion	Venues	Max Watch Issuance Lead Time	Max Warning Issuance Lead Time	Max Statement Frequency
Dew Formation	T - Td ≤ 5° F	Stone Mtn Cycling	24 hours	12 hours	1 hour
Hail	Any size	All	6 hours	As much as possible (AMAP)	15 minutes
High Heat Index	HI ≥ 100° F	All	24 hours	12 hours	1 hour
Heavy Rain	Rate > .03" per 6 min	All (see rain watch/warning)	12 hours	AMAP	15 minutes
Strong Wind	> 30 mph (see exceptions at right)	All *except:* Aquatic Ctr Diving (20) Open/Close Cer. (20) Stone Mtn Cycling (20) Lake Lanier (10)	12 hours	AMAP	15 minutes (convective) 1 hour (gradient)
Lightning	Any	All	6 hours	AMAP	15 minutes
Low Visibility	≤ 1 mile	AFC Stadium Clark-Atlanta U Morris Brown Open/Close Cer. Road Cycling GIHP Wolf Creek CSG Golden Park	24 hours	AMAP	1 hour
Rain	Any	AFC Stadium Open/Close Cer. Stone Mtn Archery Stone Mtn Tennis Stone Mtn Cycling Atlanta Beach Sanford Stadium	24 hours	12 hours	15 minutes
Wind Direction Change	> 90° in 10 minutes or less	Olympic Stadium Road Cycling Stone Mtn Cycling Wolf Creek Lake Lanier	12 hours	AMAP	15 minutes (convective) 1 hour (synoptic)

The column labeled "Max. Statement Frequency" indicates the maximum allowable interval between follow-up statement issuances.

☆ **With the watch/warning criteria thresholds so much lower than the standard NWS criteria, it was often necessary to look for the existence of first echo, and, depending on the stability of the atmosphere, decide on whether or not to issue a warning. Waiting for a storm to show up on radar was sometimes too late. Among other tools, WDSS's multi-panel display of several elevation angles at the same time was useful in these situations.**

☆ **Over 2000 bulletins were issued by the OWSO during the period of weather support for the Games. Many (over 600) were venue-specific warnings for lightning, rain, wind and high heat indices.**

☆ **The practice of issuing follow-up statements rapidly - as often as every 10 minutes during thunderstorms - until the weather episode ended made the warning program particularly successful. This impacted the operational workload, but software like WWA minimized the impact. Olympic officials commented that the continuous stream of post-warning statements made them feel that their interests were truly being tended. The ratio of statements to warnings was over 2:1.**

☆ **Customers were especially pleased with the three required elements in the discussion section of each watch, warning and advisory, i.e., when the event would start, how bad it would get, and when it would end. It is recommended that such information be included in all NWS bulletins and short-term forecasts.**

☆ **Overall warning verification statistics of the OWSO showed probability of detection (POD) and false alarm ratio (FAR) scores declined (to .89 and .31, respectively) and the Critical Skills Index improved (to .64) during the period of support. The decrease in POD scores was likely due to a reduction in "broad-brush" warnings. The decrease in FAR scores, on the other hand, was probably evidence of forecasters' increased skill with the new technology. Forecasters were in general agreement that the scores would only improve with more experience on the new technology.**

✘ **Several members of the broadcast media and some emergency management officials complained that the volume of data being issued by the OWSO was overwhelming. This is further evidence that the "resolution" of the medium by which such weather information is to be communicated *must* match the resolution of the information itself or else the benefit of new high-resolution weather technology will not be realized.**

✘ **Forecasters used the WDSS multi-panel display to locate the existence of 10 dBz or more of radar reflectivity above the freezing level as a potential indicator of lightning. This proved unreliable. Although forecasters eventually discovered a better predictor (storm top above 20,000 feet) more research is needed for "forecasting" lightning on the 10-15 minute time scale.**

Satellite OWSO Watches, Warnings and Statements

The Satellite OWSOs provided watch/warning/statement products for each of their respective venues. When any of the standard watches or warnings were issued for the county within which a satellite venue resided, those products were reformatted and retransmitted (to fax, Info'96, AFOS and WWW) automatically by software created by the OWSO Systems Administrator. French translations, however, were necessary for each of these products.

The only exception to the Satellite OWSOs issuing their own watches and warnings was in the category of tropical weather. Hurricane and Tropical Storm Watches/Warnings for the Satellite OWSOs were to be created and issued by the OWSO, following the lead of NHC.

Product Creation and Distribution

Products were distributed to multiple points. For simplicity, the single action of dragging and dropping an icon representing a file (the product) into an "Xmit" icon (or simply hitting a "Send" button) would initiate scripts that automatically transmitted the file to all appropriate recipients. The following table summarizes the origin, flow and distribution of these products.

Product	**Origin**	**Distribution**					
		VCC Fax	Info '96 (English)	Info '96 (French*)	AFOS	Home-page	Special User Fax
OWSO Forecasts	ICWF		✓	✓	✓	✓	
Satellite OWSO Forecasts, WW&S	AFOS	✓	✓	✓	✓	✓	
OMWSO Forecasts & Warnings	WordPerfect	✓	✓	✓	✓	✓	
Forecast Summary	Summary Button				✓	✓	✓
OWSO Watches, Warnings & Statements	WWA	✓	✓	✓	✓	✓	
Observations	Automatic		✓		✓	✓	

*All French translated products were sent through Meteo software.

All English language products generated at the OWSO and OMWSO were transmitted to AFOS and, by extension, to Family of Services. Olympics-related products generated by the Satellite OWSOs were transmitted via AFOS. Standard NWS watches and warnings (e.g., SVR and TOR) that had a bearing on a satellite venue were automatically reformatted, sent to Info'96 and faxed to the VCC.

Info'96 was ACOG's internal information distribution system for the Olympic Games. It contained competition results, athlete biographies and, of course, weather information. The weather information was available in French and English, with metric or non-metric units.

The OWSO homepage contained all Olympics-related products, including meteograms of surface observations and 3-D animations of RAMS from Visualization Data Explorer™. Text discussions were attached to the 3-D imagery on the web site to help explain what the user was seeing.

Watches, warnings and statements were provided to the Venue Communication Centers (VCCs) by fax and, if necessary, by direct telephone contact. UNIX scripts were written to expedite the dissemination of all Olympics-related products to the appropriate VCCs via FAX modem. Every faxed message was also faxed to The Center.

The NOAA Weather Radio (NWR) was used in support of Olympics activities. To serve foreign visitors, for example, key hourly parameters were reported in metric (mks) units. In addition, the first six-hour period of the venue-specific forecasts for the nine clusters which were prepared three times daily were recorded on NWR by the OWSO staff. These forecasts were broadcast from July 6 - August 25 (i.e., through the Paralympics).

Customer Response

A few quotes regarding the OWSO support:

Lake Lanier: "In one word - excellent!"

Athens (Sanford Stadium): "Fabulous! Absolutely tremendous!"

Columbus Golden Park: "We're exceedingly happy with support. You get an A+ from us!"

Here are a few examples of how weather support benefited the venue activities:

Opening/Closing Ceremonies: The organizers of the Opening Ceremonies in Atlanta were particularly pleased with the OWSO support leading up to the Ceremonies. The detailed forecasts of wind and clouds allowed them to make good multimillion dollar decisions for the special events.

OWSO support during the Closing Ceremonies was representative of the detail and quality of the overall support during the Games. The forecast for the time of the Closing Ceremonies was for thunderstorms in the area, but dissipating by 9:00 p.m. Indeed, thunderstorms formed late in the afternoon in and around the Atlanta metroplex. ACOG called at 6:30p.m. for a briefing of the weather situation. Despite thunderstorms literally surrounding downtown Atlanta, the forecasters analyzed the situation using the cutting-edge technology and gave an "all-clear" for the Closing Ceremonies. The forecast verified perfectly and the Ceremonies enjoyed beautiful weather. The thunderstorms surrounding Atlanta dissipated by 9:00 p.m.

Stone Mountain Archery/Cycling: At least three times, venue officials reacted to rain warnings by stowing expensive equipment. All three times, the equipment was protected because of the advance notice they were given. They also made public address announcements to clear the stands when lightning warnings were issued. The forecasts were particularly helpful in planning staffing allocation throughout the day.

In one instance, a cycling competition at the Velodrome needed 45 minutes to hold an uninterruptable race. There were rain showers in the area. The OWSO told them they had about a one-hour window before rain would begin at the site. They held the race successfully and rain started within 15 minutes of the time the race ended.

Wolf Creek: Venue officials were very happy with the instant response they received when they called for information concerning thunderstorms in the area during competitions.

Lake Lanier: The support provided by the OWSO helped them make decisions on when to get rowers out of the water and spectators out of the stands in the event of lightning in the area. Lightning was reported to have hit the finish line tower the morning of July 31, at least 30 minutes after the OWSO issued a Lightning Warning for the venue. Spectators were asked to clear the stands several times due to OWSO Lightning Warnings.

Georgia International Horse Park: A small thunderstorm passed to the south of the park, and, based on OWSO information, officials opted not to evacuate 24,000 people from their stadium unnecessarily. They were most appreciative.

Because of the High Heat Index warnings issued July 23rd, the Public Safety Officer at the Georgia Horse Park did not allow spectators to walk along the endurance course to watch the race. While there were undoubtedly some disgruntled spectators, it's a clear example of how OWSO forecasts were used to protect lives.

Alexander Memorial Coliseum: Although it was an indoor venue, officials used OWSO forecasts as a basis for opening the doors early a couple times to let people in before the rain started.

Columbus Golden Park: Heat index forecasts and warnings provided by the OWSO enabled the medical staff to raise flags alerting the spectators to heat conditions. Specific information included in warnings and statements about thunderstorms and rain allowed them to continue the games, even when threatening weather activity was nearby.

Atlanta-Fulton County Stadium: Rain watches and warnings were used to position the grounds crews to have them ready to cover the field with tarp at a moment's notice.

Aquatic Center: Based on lightning warnings received, officials used the public address system to ask spectators to clear the stands during competitions. This happened a couple times.

The Omni (indoor): Weather warnings resulted in an "all-call" to volunteers inside and outside to hold up a fence that blew down easily and could have injured spectators.

Georgia Dome (indoor): Weather information helped in decisions on whether or not to let people in early. Based on forecasts and warnings, they opened the venue early or hurried people out the door at the end of the competition.

Georgia State Univ. (indoor): Officials used weather information to decide on early opening of the venue for spectator queues outside.

Morehouse College (indoor): Used weather information to decide on early opening for spectator queues outside and to monitor the safety of the staff, delivery, logistics and security personnel outside. Warnings, as soon as they were received, were announced to all support staff.

Delegation Welcome Center (indoor): Warnings of rain and thunderstorms were relayed to transportation and security people so they could move newly-arriving athletes and dignitaries to shelter. This occurred several times.

UGA Coliseum: Lightning struck the stadium at 8:30p.m. on July 14. No competitions were being held at the time, but the OWSO had issued a lightning warning 48 minutes prior to the strike.

b. Olympic Marine Weather Support Office

Training

During the summer of 1995, all OMWSO forecasters and alternates received orientation training on the workstations and operations to be used during the Olympics. Actual workstation training was accomplished at Peachtree City after which time the forecasters traveled to Savannah to provide forecast support for an international sailing regatta in much the same way they would support the 1996 Olympics. While the OMWSO was not fully equipped at that time, the forecasters learned the basic requirements of the program and provided management with invaluable comments of improvements needed to adequately support the Olympic Games the following year.

Period of Operations

While supporting the Yachting Venue during the Olympics, the OMWSO maintained the hours of the venue management. The first shift of forecasters arrived each morning at 0500 to prepare the morning forecasts. A series of briefings by the MIC between 0700 and 1000 to the Venue Management, Venue Sports Officials and competition team meteorologists/coaches provided the venue conditions expected throughout the day. (Venue management requested that the MIC only provide these briefings for the sake of familiarity and consistency.) During the critical race periods, written forecast updates and observations were provided each hour between 1200 and 1800. These hourly forecasts were provided directly to venue management via fax and backed up by telephone as needed. Of course, during watch and warning conditions, updates were provided more frequently as needed.

Products and Services

Forecasts and warnings were distributed to ACOG and within the venue in many ways. (1) Three times a day, forecasts were sent to Info'96. As issued, watches and warnings were also sent into Info'96. This procedure was similar to that used at the OWSO. (2) Forecasts, and warnings were distributed to venue management and the U.S. Coast Guard via fax. (3) Frequent updates of the

Savannah NWR were maintained by NWSO Charleston. During periods of high use by the venue, the broadcast schedule was revised to emphasize Olympic marine weather. (4) Forecasts and warnings were broadcast over the venue PA system in both English and French. (5) Of course, the personal presence of the forecast staff within the venue made possible personal contacts throughout the day as weather-related questions and concerns arose.

During the afternoon competitions, a forecaster was always within the offshore field-of-play, aboard a dedicated weather boat made available by venue management. The weather boat was staffed with a captain and mate and was available during the day. Besides providing 'eyes and ears' in the racing area, the weather boat was used to transport personnel to service the buoys and a coastal mesonetwork site.

In addition to a forecaster onboard the weather boat, the OMWSO always staffed a forecaster at the Day Marina in Wassaw Sound during the afternoon races. The Day Marina served as a large floating platform from which the afternoon venue operations were centered. Venue management and competition teams operated from there during race times. The forecaster on duty was able to interact with venue management and help interpret conditions, forecasts and warnings. As with the weather boat, the Day Marina forecaster communicated with the OMWSO via cellular telephone.

☆ **During the summer 1995 trials, it became obvious of the need for additional NWR availability. Two special solar powered NWR receivers were built by the ET staff of Peachtree City and placed in the Yachting Venue -- one on the Day Marina and the other on the Olympic Marina. These sets had a push-to-listen speaker capability which cut off after about 5 minutes. This on-scene availability of NWR was very popular at the venue.**

Customer Use of Support

As the OMWSO was beginning to shut down operations after the closing ceremonies, several team meteorologists from foreign countries came by to look over the technology and to discuss the program. Probably the most gratifying comment was made by the French meteorologist who stated that the OMWSO "won the gold medal of the forecasters" and that his job was made easy because of the accurate, complete and responsive nature of the OMWSO program.

The goal of the OMWSO was to provide the best possible weather support to the Yachting Venue. The products provided were directly in response to the expressed needs of the customers. Almost to the end of the competition, minor changes in the service program were made in response to requests by the venue management and competition teams. Flexibility became the rule.

7. Overall Evaluation

One of the most frequently-asked questions about all the new tools available to forecasters was whether or not they felt they had too much data. Perhaps not surprisingly, the answer was "No," but with a caveat. Forecasters felt they did not have too much data as long as they could rapidly access the information they needed. Data only became overwhelming when it (the data) could not be acquired/accessed in a timely fashion.

A few forecasters had difficulty adjusting to the mesoscale forecasting tasks, in that they would occasionally rely on synoptic scale forecasting techniques when mesoscale techniques were required. This was not a serious problem, and by the end of the Games, most were deeply involved in mesoscale forecasting, when appropriate. Nevertheless, this trait points to the need for continued mesoscale forecasting training in the NWS.

The overall Olympic weather support project can be summed up by an Associated Press reporter who opined that weather did not have an impact on the Games. The fact that this reporter (and several others) did not notice the weather's impact, despite almost daily bouts of thunderstorms, rain, and/or heat at every venue during the 17 days of the Games, testifies to the excellent job performed by the staff of the two OWSOs. No one was killed or suffered significant harm due to weather, and property damage was minimal. The primary and simple reason for this is that the OWSO and the OMWSO staffs did their job - and did it well.

8. Partnerships

a. Public/Private Partnerships

Much of the technology used in the OWSS did not exist in the operational environment of the NWS. It was either still under development in various laboratories, or was awaiting the arrival of sufficient computer capability at NWS field offices to allow its incorporation into operations. In a few instances, some of the OWSS technology was not even planned for incorporation in the field operations of the NWS. Consequently, the development and implementation of the OWSS would not have been possible without an extraordinary degree of collaboration and cooperation among a diverse group of public and private sector organizations. As news circulated about the NWS having been designated as the provider of weather support for the 1996 Olympic Games, entities within the Agency, within NOAA, and other public and private sector organizations began approaching the NWS's Olympic Weather Support Committee with offers of assistance, products and services (see Appendix C for a listing of those providing support.)

b. Public Sector

The National Centers for Environmental Prediction offered, and subsequently provided, their N-AWIPS software, assisted in configuring the OWSS's communications network, and helped set up critical security measures. The NCEP also provided special guidance support by running high resolution versions of the Eta model tailored for the Olympic weather support effort (Black, et al. 1997), and provided special marine forecasting assistance to the OMWSO. The CPC also provided special extended forecasts (6 days to 6 months) for the Olympics.

N-AWIPS was developed by the NCEP Central Operations/Computing Development Branch (NCO/CDB) and served as a main component of the integrated workstation used by Olympic forecasters. NCO/CDB developed many enhancements for the N-AWIPS software, tailored towards the specialized needs of the OWSS.

NCEP was the vital component in the NWS Olympic support effort in terms of communications. Every bit of data available to forecasters at the OWSS was there because of NCO, with the majority of support provided by the Users Support Services Group (USSG). NCO/USSG made significant contributions to many phases of the entire NWS Olympic support effort, including the development of a new data transport system called Distributed Brokered Networking (DBNet). DBNet was created in response to ever-increasing demands for data in support of the Olympics. DBNet has already set precedence in its value to the entire NCEP operational data flow system. As a direct result of the Olympics, a superior data transport system has arisen, and it serves as an Olympic legacy. (Young 1996)

The Forecast Systems Laboratory of NOAA's Office of Oceanic and Atmospheric Research (OAR) and the Colorado State University RAMS software (Edwards, et al. 1997; Snook, et al. 1997; Stamus, P.A., 1996; Stamus and McGinley, 1997). FSL contributed LAPS. In addition, FSL provided extensive staff resources to tailor the LAPS and RAMS for use in Georgia, and to assist the OWSO and the OMWSO in forecasting using the system. The FSL also collaborated closely with the NCEP in developing procedures to use data fields generated by NCEP models; data fields necessary to initialize the RAMS.

The National Severe Storms Laboratory of NOAA's OAR provided its WDSS (Johnson, et al., 1996), and a scientist to serve as the SOO of the OWSO. Additionally, several NSSL employees assisted in installing WDSS at the Peachtree City OWSO and Charleston, South Carolina, for the OMWSO access. When color table conflicts arose between the WDSS and the N-AWIPS software, the problems were resolved by a collaborative effort involving NSSL and NCEP employees. NSSL also provided a lightning climatology for each Olympic venue.

The Techniques Development Laboratory of the Office of Systems Development at NWS Headquarters provided its ICWF and WWA software and provided extensive staff resources to configure the software for Olympic weather support. TDL also collaborated with NCEP in developing techniques to allow the ICWF to initialize on model gridpoint data in addition to model output statistics.

The National Environmental Satellite, Data and Information Service (NESDIS) and the NCEP Storm Prediction Center (SPC) assisted with special satellite imagery. The SPC also provided severe weather briefing support to the Olympic Torch relay during its 10,000 mile journey across the United States. The National Data Buoy Center provided specially-designed data buoys strategically positioned to support the weather support for the yachting venue. The U.S. Coast Guard provided offshore transportation for deploying the buoys and for transporting technicians to the buoys when maintenance was needed. The Environmental Technical Laboratory of NOAA's OAR provided use of a mobile wind profiler to support forecasting operations at the OMWSO.

The Cooperative Institute for Research in the Atmospher (CIRA) provided RAMSDIS and special satellite discussions to support operations at both the OWSO and the OMWSO.

When it was time to assemble and configure the hardware and communications of the OWSS, the support of system architects, computer security experts and electronics technicians from NCEP, NWS Southern Region Headquarters, NOAA's Mountain Administrative Support Center, and the Peachtree City NWFSO/RFC was invaluable.

NOAA's Office of Public Affairs provided extensive support in publicizing the Olympic Weather Support story, and collaborated with the World Meteorological Organization in publicizing the role of meteorology in sports. The Public Affairs Office also worked with the WMO and the IOC in developing and distributing a wallet-sized card which provided information on the Heat Index.

In keeping with the Olympic Charter's fundamental principal of "creating international goodwill", the NWS also collaborated with the Australian Bureau of Meteorology (BOM), the National Meteorological Service of France (METEO, France), and the Canadian Atmospheric Environment

Service (AES). The AES provided four of their meteorologists to assist in the forecasting effort and in the quality control of the translation of narrative English products into continental French. The BOM meteorologists also assisted in the forecasting and were gaining insight into Olympic weather support requirements in preparation for the 2000 Games to be held in Sydney. The NWS called on METEO, France, to assist the ACOG in translating into continental French, a glossary of meteorological terms commonly used in weather forecasts and warnings in the United States.

c. Private and Academic Sectors

Many in the private sector and the academic community provided collaboration, as well. IBM loaned a high-end parallel processing computer (RISC/6000 SP2) to enable FSL to run the RAMS at the OWSO (Christidis, et al. 1997). IBM also provided extensive technical assistance of several scientists to help in configuring the RAMS to run on the SP2, and in tailoring the Visualization Data Explorer™ software to display the output of the RAMS (Treinish and Rothfusz 1997). NEC, Inc. loaned a high resolution, 37" RGB monitor to display the output of the Visualization Data Explorer™ in the OWSO media briefing room.

John Chandioux Consultants, Inc., provided their METEO 96 translation software (and a considerable amount of support time) to facilitate the translation of narrative products prepared in English into continental French, a requirement of the International Olympic Committee (Chandioux and Grimaila 1997).

Cray Research, Inc. provided access to a C90 "supercomputer" to enable NCEP to run the 10 km Eta model for Olympic support (Black, et al. 1997). The University of Georgia and the Georgia Forestry Commission provided access to their automated meteorological observing systems positioned throughout Georgia (Garza and Hoogenboom 1997), and the Georgia Environmental Protection Division provided air quality data on a daily basis. The University of Georgia Agricultural Department was especially helpful in placing and maintaining mesonetwork sites at several venues.

Florida State University and Texas A&M University conducted special meteorological studies. Georgia Tech Research Institute provided a backup connection to the Internet, and the Skidaway Institute of Oceanography provided ocean current information and studies for the OMWSO. The Oklahoma Climate Survey allowed use of its quality control software for monitoring output of the automated meteorological observing stations being used in the mesonet, and Colorado State University provided permission to use its RAMS model; a crucial component of the support effort.

The Atlanta Committee for the Olympic Games (ACOG) worked, on an almost daily basis, with the OWSO and the OMWSO in defining and refining requirements, in developing communication procedures and protocols, contingency plans, briefing procedures, and in developing procedures for product composition and format.

d. Special Recognition

While many entities in both the public and private sectors provided significant material resources, the individuals who contributed to the project are worthy of special recognition. These are the people who had the vision to see what could be done, and then took the steps necessary to make it happen. Appendix D provides a listing of the names of these people. While some played a larger role than others, the contributions made by each and every one of these individuals helped ensure the ultimate success of the project.

e. Summary

From international corporate giants such as IBM and NEC, to smaller companies such as John Chandioux Consultants, to the Federal meteorological services in the United States, Canada, France, and Australia, to the individuals involved, the level of cooperation and collaboration in the weather support effort for the 1996 Olympic Games was unprecedented and phenomenal.

The unique combination of interdisciplinary cooperation and public-private sector partnerships enabled the National Weather Service to provide a level of weather support to the Games which was equally unprecedented in the history of the Olympiad. The Centennial Olympic Games were characterized by cutting-edge technology in numerous areas. Weather support was acknowledged as one of these areas. The legacy of weather support for the XXVI Olympiad will not only benefit future Olympiads, but will benefit the American public as a whole, as the technologies used in weather support for the '96 Games are incorporated into the public and private sector weather services of the future.

9. Observations and Recommendations

a. Overall Observations

- Locally-controlled, regional models have significant benefit to forecasts and warnings.
- For new weather technology to be most effective, the means by which information is communicated must have resolution and accessibility comparable to the resolution and other capabilities of the technology creating the data. As it was, NOAA Weather Wire users either could not access Olympics products or the volume of data became overwhelming.
- Forecasters do not think they have too much data, as long as they can access the information they need rapidly.
- Some forecasters are reluctant to abandon synoptic-scale forecasting techniques, even when mesoscale tools are conveniently available. This "problem" decreased as training and experience increased.
- Developers of hardware and software who spend time with forecasters in an operational setting deliver a significantly improved product. The rapid implementation of the OWSS was achieved because several talented meteorologists/programmers who would use the system during the Games were either intimately involved in the development process, or were the developers themselves.
- Info'96 suffered significantly. Developers needed closer collaboration with NWS officials.
- Quality control volunteers for ACOG proved crucial to ensuring quality weather information disseminated via Info'96.
- Law enforcement agencies established multiple "coordination centers", making NWS coordination more challenging.
- NWS presence at coordination centers was valuable during Hurricane Bertha and immediately after the Centennial Olympic Park bombing, but was of limited practicality most other times.
- LAPS was a critical tool in all mesoscale forecasting situations.
- ISP (the UNIX version of SHARP) could not be run simultaneously with some other applications due to color table conflicts. One sure way to prevent a tool's use is to make it conditionally accessible.
- ICWF was essential to creating more useful forecasts.
- Some forecasters had difficulty making ICWF text "say" what they wanted, because ICWF's customization for the Olympics spawned bugs not found with the standard ICWF package.
- A user-friendly interface, the ability to issue a warning from the same screen displaying radar data, tracking of valid and expired warnings, and automated reminders for issuance of updates made WWA an exceptional tool for warning operations.
- WDSS was the most utilized and popular OWSS program. It was the "star" of the OWSS.
- RAMSDIS, along with WDSS, formed the core of the OWSO warning operations.

- It was serendipitous that RAMSDIS was not integrated into the OWSS because it was helpful to have a stand-alone satellite display constantly looping images nearby.
- There is widely-recognized potential for a fully-configured Coach, even though it was not useful in OWSO operations because of the lack of sufficient data in the database.
- GARP was not ready for operational use.
- DX images of RAMS were exceptional. Data were easily understood by non-meteorologists and added value over 2-D images for meteorologists. Most popular were the 3-D animations of clouds, rain (dBz), total precipitation and winds.
- The Meteo 96 translation software was successful due to the preparation in developing the software. Subjectively, the accuracy of translation was about 80%, but it improved over time. Still, that rate usually allowed the translators to keep pace with the volume of products that were being issued during active weather situations.
- DBNet proved to be a reliable and robust data communications solution during normal and contingency operations (such as a network outage).
- The performance of the LDM was exceptional during normal operating conditions but suffered reliability problems during contingency operations.
- Meta file dissemination from NCEP did not use DBNet and often proved to function unreliably causing meta files to arrive too late for operational use or not at all.
- The Bastion Host was supposed to provide security for the most network traffic. As the network load increased, a kernel bug surfaced which resulted in "hung" ftp sessions. Thus, the Bastion Host was configured for a reduced level of security.
- A "product distribution spooler" program developed at the OWSO provided an easy method by which to make modifications to whom, where and when the products were transmitted.
- The WWW homepage provided an invaluable means by which to communicate non-time-critical information.
- Fifteen-minute mesonetwork collections were valuable in creating better forecasts and warnings, especially at such increased geographic density.
- Mesonetwork data quality was a major concern. Relative humidity measurements tended to drift with the temperature. Sitings of some of the sensors were poor.
- The high-resolution satellite data (to 1 km on visible channel) was invaluable to forecast and warning operations.
- There was no consensus that 7.5 minute satellite imagery scans had any advantage over the normal 15-minute scans.
- In general terms, the Eta-10 handled synoptically-forced situations very well while RAMS did better on purely mesoscale phenomena (e.g., timing and location of convective initiation, timing and strength of the sea breeze, etc.).
- The lack of experience with the Eta-10, and its associated data volume, on the part of forecasters, system administrators, developers and managers proved to be a major hindrance to the complete implementation and use of this model. Its arrival was intermittent due to model failures on the CRAY, communications programming errors, system configuration problems, and/or simple miscommunication between NCEP and

OWSO personnel. Nevertheless, most forecasters used the data when they arrived and found them to be quite good.

- The most positive impact on mesoscale forecasting operations was that RAMS was run on a frequency matching the mesoscale time scale. Comparing output from sequential RAMS runs proved effective in predicting how the mesoscale environment was changing. If the Eta-10, by comparison, missed its prediction, the next solution arrived 12 hours later.
- All the training provided was essential and effective, including the training/dry run one year ahead of time. Most forecasters were comfortable on the technology within one week. All forecasters but one said they were adequately trained.
- Most forecasters liked ten-hour shifts, although the 10-hour midnight shift was somewhat difficult to endure.
- The narrative text products divided into six-hour segments gave customers a clearer picture of what to expect at certain times of the day and were extremely well-received.
- The matrix format forecasts were equally well-received. Several venue activity planners commented positively on the value of this format.
- Presumably due to the novelty of the matrix format, few media outlets used this product. With additional education of the media, such formats could be used to generate time series diagrams.
- Climatological data from mesonetwork sites at venues were not completed in adequate fashion for forecasters to utilize them in their forecasting routines. As a result, localized phenomena were not known and were forecast poorly.
- The Forecast Summary was more popular than anticipated and had to be developed late in the planning process. A single, widely-distributed "forecast overview" product should have been developed at the outset.
- Interobs were shown to be a practical concept; however, they were not good at handling situations in which localized weather phenomena occurred (e.g., nocturnal radiational cooling.)
- Over 2000 bulletins were issued by the OWSO during the period of weather support for the Games. Many (over 600) were venue-specific warnings for lightning, rain, wind and high heat indices.
- Overall warning verification statistics of the OWSO showed probability of detection (POD) and false alarm ratio (FAR) scores declined (to .89 and .31, respectively) and the Critical Skills Index improved (to .64) during the period of support. Forecasters were in general agreement that the scores would improve with more experience on the new technology.
- Locating the existence of >10 dBZ above the freezing level as a potential indicator of lightning proved unreliable. Although forecasters eventually discovered a better predictor (storm top above 20,000 feet) more research is needed for "forecasting" lightning.

b. Recommendations

- Frequent and early interaction between the NWS and Olympic customers was essential. Those responsible for planning future projects of this nature should begin such interactions from the outset of the project. Similarly, frequent interaction between the NWS and its "regular" customers is strongly recommended.
- N-AWIPS performed well for synoptic-scale forecasting. In a mesoscale forecasting situation, however, forecasters must have the ability to control the domain, contours, appearance and combinations of graphical data in real-time.
- At least two monitors are needed at each forecaster workstation.
- Local control of the RAMS was of significant benefit to the forecasters. Initialization time, location and resolution (8 km vs. 2 km) could all be determined "on-the-fly." Thus, forecasters could apply the model directly to the forecast problem of the day. It is recommended that forecasters be allowed to control regional models runs - even if remotely to a centralized facility housing multiple, large capacity computers.
- Some forecasters felt ICWF's *only* benefit was as a vehicle for putting their forecasts in the required, high-detail formats and that it did not allow them to spend more time on meteorology. We suggest, however, that customers are better served with greater-detailed products using present-level meteorology than with better meteorology in products at their present level of detail.
- The mesocast form helped forecasters track and focus their thoughts on possible mesoscale forcing mechanisms. It is recommended that a similar (software?) device for tracking mesoscale features - even for long periods of time - be devised for NWS operations.
- Real-time feedback provided by automated meteograms comparing observations with forecasts should be standard among operational tools in the NWS.
- Teamwork between a mesoanalyst and a radar interpreter significantly improved the overall quality of the support and, despite the integration of the software on the workstations so that one person could do it all, two meteorologists were still required to ensure the best science would be applied to warning operations. Until it can be operationally demonstrated otherwise, the NWS should plan for such staffing at field offices when short-fused warning operations are in progress.
- The practice of issuing follow-up statements rapidly - as often as every 15 minutes during thunderstorms - until the weather episode ended made the warning program particularly successful. The ratio of statements to warnings was over 2:1. Such a practice is recommended for standard NWS operations.
- Customers were especially pleased with the three required elements in the discussion section of each watch, warning and advisory; when the event would start, how bad it would get, and when it would end. It is recommended that such information be included in all NWS bulletins and short-term forecasts.
- Although the NWS uses heat index as its measure of apparent temperature, the sporting industry uses wet-bulb globe temperature (WBGT). Future support for sporting events should seriously consider including the WBGT as a measured and forecast parameter.

- The broadcast media and some emergency management officials complained that the volume of data being issued by the OWSO was overwhelming. The "resolution" of the medium by which such weather information is to be communicated must match the resolution of the originating technology, otherwise the benefit of new weather technology will not be realized.
- Most of the technical support staff's time during the Games was spent trying to find the best balance in sending faxes via the four fax servers and monitoring the faxes themselves to ensure they were successful. Faxing is not a viable means of sending warnings and should not be considered as a means of disseminating warnings in the NWS.
- The translation workload was such that the AES meteorologists rarely had opportunities to become fully-immersed in meteorological operations. This was a waste of talent. Future activities requiring translation should consider the use of dedicated translators (versus bilingual meteorologists).
- Maintaining the underlying system integrity, data flow, data storage, communications, etc. of an AWIPS-like system requires nearly full-time attention by a single systems administrator. The NWS needs to plan for this eventuality in the "AWIPS-era" NWS.
- Media-related support is needed during major projects to ensure smooth interaction with the media. Until the Centennial Park bombing occurred, media activity was intense, averaging at least eight contacts per day.
- Organizers of similar support projects in the future should anticipate interest in international weather data. It should also be noted that data *must* be made available for any cities bidding on future Olympic Games (winter or summer) to avoid embarrassment of the officials visiting from those cities.
- Organizers of similar support projects in the future should consider providing support for a few days following the end of the events. Staffing should be cut back corresponding to the diminished workload as competitions and activities draw down.

10. Summary

The Olympics weather support project provided tremendous opportunities to evaluate planned and potential NWS operational practices and technology in a real-world setting. By all accounts, it was a tremendous success. Representatives of the media, ACOG, law enforcement, NOAA, NWS, Dept. of the Army, IBM, foreign meteorological programs, and others were extremely impressed with what was assembled and, more important, what support was delivered.

It would be inappropriate to pass judgement - either good or bad - on the NWS modernization based on the experiences of this unique project. The Olympics forecasters cautioned against this, as well. However, this project has given a preview of possible future forecasting operations (especially mesoscale); a preview which can benefit any meteorological organization. From what we've seen, the future is challenging, yet it also holds the potential for some extraordinary rewards!

References

Black, T., G. DiMego, and E. Rogers, 1997: High Resolution Numerical Guidance from NCEP's Eta Model for the 1996 Olympic Games. Preprints *13th Intl. Conf. On IIPS for Metr., Ocean., and Hydr.* (Long Beach), AMS.

Chandioux, J., and A. Grimaila, 1997: Preparing for and Delivering Multilingual Weather Support. Preprints *13th Intl. Conf. On IIPS for Metr., Ocean., and Hydr.* (Long Beach), AMS.

Christidis, Z., J. Edwards, and J. Snook, 1997: Regional Weather Forecasting in the 1996 Olympic Games Using an IBM SP2. Preprints 13th Intl. Conf. On IIPS for Metr., Ocean., and Hydr. (Long Beach), AMS.

Edwards, J., Z. Christidis and J. Snook, 1997: Forecasting for the 1996 Olympic games with the NNT-RAMS parallel model. Preprints 13th Intl. Conf. On IIPS for Metr., Ocean., and Hydr. (Long Beach), AMS.

Garza, C., and G. Hoogenboom, 1997: Success experienced in the use of diverse surface weather data collection systems in support of the 1996 Olympic games. Preprints 13th Intl. Conf. On IIPS for Metr., Ocean., and Hydr. (Long Beach), AMS.

Hart, J.A. and W.D. Korotky, 1991: The skew-T/hodograph analysis and research program for the IBM and compatible PC. User's Manual. NOAA/NWS Forecast Office, Charleston, WV., 62 pp .

Johnson, J.T., M.D. Eilts and L.P. Rothfusz, 1996: Weather information display, analysis and product generation tools used in support of the 1996 Summer Olympic Games: Warning tools. *12th Intl. Conf. on IIPS for Metr., Ocean., and Hydr.* (Atlanta), AMS.

Rothfusz, L.P., J.T. Johnson, L.C. Safford, M.R. McLaughlin, and S.K. Rinard, 1996a: The Olympic Weather Support System. Preprints *12th Intl. Conf. on IIPS for Metr., Ocean., and Hydr.*(Atlanta), AMS.

Rothfusz, L.P., J. Noffsinger, M. Peroutka, S. Schotz, and J.T. Johnson, 1996b: Weather Information Dsiplan, Analysis, and Product Generation Tools Used in Support of the 1996 Summer Olympic Games: Daily Forecasts. Preprints *12th Intl. Conf. On IIPS for Metr., Ocean., and Hydr.* (Atlanta), AMS.

Snook, J., Christidis, Z., and Edwards, J., 1997: Forecast results from the local-domain mesoscale model supporting the 1996 Olympic games. Preprints *13th Intl. Conf. On IIPS for Metr., Ocean., and Hydr.* (Long Beach), AMS.

Stamus, P., and J. McGinley, 1997: The Local analysis and prediction system (LAPS): Providing weather support to the Olympic games. Preprints *13th Intl. Conf. On IIPS for Metr., Ocean., and Hydr.* (Long Beach), AMS.

Treinish, L., and L. P. Rothfusz, 1997: Three Dimensional Visualization for Support of Operational Weather Forecasting at the 1996 Centennial Olympic Games. Preprints *13th Intl. Conf. On IIPS for Metr., Ocean., and Hydr.* (Long Beach), AMS.

Young, S. K., 1996: NCEP Olympics Support: A Post-mortem Review. NWS Internal Report for the Director, NCEP.

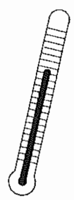
Appendices

Appendix A

HOW TO INTERPRET AND USE NWS WEATHER INFORMATION DURING THE OLYMPIC GAMES

Prepared for ACOG by the National Weather Service

This brief document answers some of the questions people often have about weather information. It touches on weather observations, forecasts, and special bulletins - all of which will be available to you from the National Weather Service via Info '96. Therefore, this document is intended to give you the knowledge of how to make the best possible use of the weather information provided during the 1996 Olympic Games.



WHAT'S A WEATHER OBSERVATION?

Basically, a weather observation is a *measurement.* Several weather elements are measured to determine the *present* conditions of the atmosphere. Info '96 will display these measurements under the heading "Present Conditions." During the Olympics, we will take observations of the following weather elements:

- Sky Condition: The amount of clouds in the sky. In general terms, we will report the sky as clear, partly cloudy, mostly cloudy, and cloudy. So, what's the difference between partly cloudy and mostly cloudy? "Partly cloudy" means one-half or less of the sky is covered by clouds. "Mostly cloudy" means more than half the sky is covered by clouds.

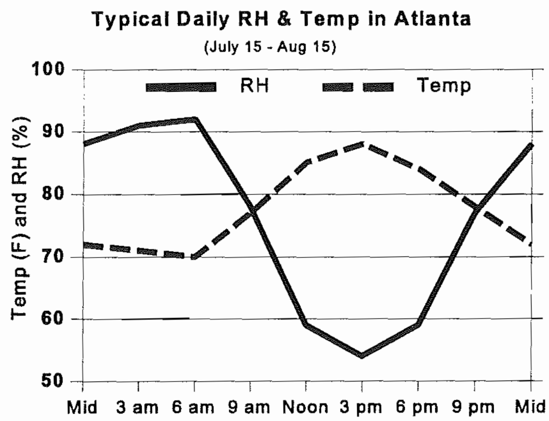
- Significant Weather: Any form of precipitation, limitation to visibility, or other significant weather phenomenon at the time of the observation. Info '96 will include observations of these weather phenomena:

  Thunderstorms (technically, rain showers with lightning)
  Heavy rain (rain falling at more than .03 inches or .08 cm in 6 minutes)
  Light rain
  Dense fog (visibility less than 1 mi or 1.6 km)
  Light fog
  Wind (greater than 30 mi/hr or 48 km/hr).

- Air Temperature: How warm or cool the air is in the shade.

- Relative Humidity: How much the air is laden with water vapor (expressed as a percent). At 100 percent relative humidity, the air holds as much water vapor it can. Most people think the relative humidity stays the same throughout the day. Not so! If the amount of water vapor in the air stays constant (which it usually does), the relative humidity actually falls as the temperature rises. That's why we call it *relative* humidity! The humidity is relative to the temperature. The chart on the next page shows how relative humidity and temperature change throughout a typical summer day.

- Dewpoint Temperature: Remember, as temperature decreases, the RH increases. When the temperature decreases to the point at which RH = 100%, the air can hold no more water vapor and condensation (dew, clouds or fog) begins to form. This temperature is the *dewpoint temperature.* Dewpoint temperature is always less than or equal to the temperature. An example of dewpoint temperature in "action" is the early morning fog that results when temperatures drop overnight to meet the dewpoint temperature.



- Barometric Pressure: High or low depending on the density and temperature of the air. High pressure (above 30.00" or 762 mm of mercury) is usually associated with fair weather, while low pressure is associated with stormy weather. If pressure is falling over and extended period of time, it may mean that inclement weather is on the way.

- Wind Direction and Speed: The average direction from which the wind is blowing and how fast it is blowing. Significant gusts above the average speeds are included, if observed.

- Heat Index: An indicator of the degree of human discomfort due to temperature and humidity. More on this later.

- Air Pollution Index and Levels: An air quality index prepared by the Georgia Environmental Protection Department. Chemical constituents such as carbon monoxide and ozone, along with particulates such as soot, are measured on a variety of scales. Generally speaking, however, the smaller the number, the cleaner the air.

- Wave Height and Period; Ocean Water Temperature; and Ocean Current Speed: These data describes the condition of the ocean surface and near surface currents. Applications will be only for the yachting venue at Savannah, Georgia.

- Rainfall: The amount of liquid precipitation received in the last 15 minutes, and a running total since midnight.

How often are observations of the Present Conditions taken?

Ordinarily, National Weather Service observations are required at least every hour on the hour - more often during rapidly changing conditions. During Olympics support operations, however, observations will be taken every 15 minutes with special sensors at or very near each venue. The following table shows the locations of these special sensors and the venues each will "support."

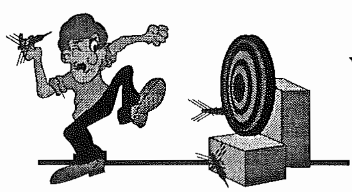
How can weather observations be used?

There are numerous applications. Here are a few:

- Observations of rain showers will alert officials and athletes in outdoor events that the field of play has become wet and may alter performances, or even require postponement.

- While the ultraviolet index (UVI, see below) is not a measurable observation, sky condition gives a qualitative indication of how much the sun will add to heat stress on people.

- The heat index measurements will be particularly valuable. As described below, heat stress can be a subtle killer. Keep an eye on the heat index observations to be aware of the stress that the heat and humidity quietly may be taking on you and those around you.



WHAT ABOUT CONDITIONS TOMORROW OR THE NEXT DAY?

That's *forecasting* and, no, we don't use dart boards! As a first step toward forecasting, weather observations are collected and used to initiate computer simulations of the atmosphere called models. These models are actually complicated mathematical equations that predict changes of key weather elements (temperature, pressure, wind, etc.). This gives forecasters the ability to estimate the future state of the weather. Unfortunately, these equations don't provide perfect solutions, so the forecast accuracy decreases as one tries to forecast farther out in time. The forecaster's *main* objective is to make the best possible interpretation of the models, tempered with experience, and produce as accurate a prediction as possible.

What types of forecasts will be available during the Olympics?

Info '96 will display two basic types of forecast formats: *Narrative Text* and *Graphic*.

Narrative Text forecasts will be plain language predictions of sky condition, temperature, wind direction and speed, and chance of precipitation for the current day, the next day and days 3-5.

- The forecasts for the current day and the following day (called *Today's Forecasts* and *Tomorrow's Forecast*) will each be divided into four 6-hour periods as shown in the following example:

  Midnight to 6 am... Clear. Temperature falling from 79 to 68 F (26 TO 20 C). Wind light and variable.

  6 am to Noon... Clear. Temperature rising from 68 F early to 80 F by noon (20 to 27 C). Wind from the south at 5 to 10 mph (8 to 16 kph).

  Noon to 6 pm... Partly cloudy. Temperature rising from 80 to 95 F (27 TO 35 C). A slight chance of thunderstorms...mainly after 3 p.m. Wind from the southeast at 5 to 10 mph (8 to 16 kph). Chance of precipitation 20 percent.

  6 pm to Midnight... Partly cloudy. Temperature falling from 93 to 70 F (34 to 21 C). Wind from the southeast at less than 5 mph (8 kph).

- The extended forecasts (called the *Day 3-5 Forecast)* will be a generalized description of the whole of each day.

Graphic format forecasts will be generated and displayed by Info '96, but the graphics will be based on NWS forecasts for specific weather elements at 3-hour intervals. In other words, these graphics will show what each of the following weather elements are forecast to be every three hours from the "present" time until "tomorrow night":

Temperature	Relative Humidity
Probability of precipitation (POP)	Probability of thunderstorms (POT)
Ultraviolet Index (UVI)	Dewpoint
Heat Index	Wind Direction/Speed/Gust
Sky Condition	Significant Weather (fog, rain, etc.)
Wave Height/Direction/Period	Ocean Current Speed

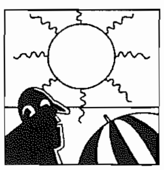
What does probability of precipitation or thunderstorms mean?

The *probability of precipitation* is the *likelihood of measurable precipitation* amounts (at least .01" or .03 cm) occurring at any point within the area for which the forecast is valid and during the time for which it is valid. The probability is expressed as a percent. For example, let's say Info '96 shows a 30 percent probability of precipitation at Stone Mountain for the period 6 a.m. to 9 a.m. This means each person at the Stone Mountain venue has a 3 in 10 chance of receiving .01" (.03 cm) or more of precipitation between 6 and 9 a.m. Similarly, the probability of thunderstorms is the percent probability of a thunderstorm at any point within the forecast area.

It is not necessary to know the size of the forecast area because the probabilities apply equally to every point in the area. As long as you read the forecast for the area in which you are standing, the probability applies to you individually as well as to every other point in that area.

How you use these probabilities is up to you. Each of you will have different thresholds at which you will take precautionary measures that undoubtedly cost time and money (e.g., ensuring ponchos are available, postponing training and competition, etc.). For some of you, getting soaked by rain is not a serious problem, so you can risk waiting until the probabilities of precipitation are rather high before taking any costly precautionary measures.

For others, however, even the lowest probabilities of precipitation may be considered too great a risk of getting wet. Thus, you may opt to take precautions that are costly, but cheaper than the loss you will suffer if you get wet. Whatever the case, you will need to decide beforehand what your thresholds for taking action are.



What about the Ultraviolet Index or UVI?

The UVI is a number that shows the degree of exposure to ultraviolet radiation from the sun's rays. It is determined based on sun angle, cloud amount, and time of day. The higher the number, the greater the exposure as shown in the table below.

Physicians and scientists worldwide agree that anyone exposed to moderate or higher UVI incurs risk for developing skin cancer, cataracts, premature skin aging, and perhaps even decreased immunity to disease.

UVI	Exposure
0 - 2	Minimal
3 - 4	Low
5 - 6	Moderate
7 - 9	High
10+	Very high

The easiest way to guard against too much UV is to limit your exposure to the sun, especially during the sunniest part of the day from 10 AM to 4 PM. People can limit their exposure by wearing lightweight, long-sleeve shirts, wide brim hats, and sun glasses that filter 99 to 100 percent of UV rays. They should also use a sun screen with at least SPF-15.

What is the Heat Index?

The heat index (HI) is an apparent temperature felt by the human body due to the combined effects of temperature and humidity. Due to the prevailing humid conditions in the summer, the heat index can cause problems as the daytime temperature rises. The tables below show heat index categories and possible effects on people. Keep in mind that the heat index applies to a lightly-clothed, medium-framed human standing in light wind and shade. The heat index increases as clothing, body weight, sun exposure, and/or physical activity increase.

HEAT INDEX °F (° C)

TEMPERATRURE °F (°C)	RELATIVE HUMIDITY (%) 40	45	50	55	60	65	70	75	80	85	90	95	100
110 (47)	136 (58)												
108 (43)	130 (54)	137 (58)											
106 (41)	124 (51)	130 (54)	137 (58)										
104 (40)	119 (48)	124 (51)	131 (55)	137 (58)									
102 (39)	114 (46)	119 (48)	124 (51)	130 (54)	137 (58)								
100 (38)	109 (43)	114 (46)	118 (48)	124 (51)	129 (54)	136 (58)							
98 (37)	105 (41)	109 (43)	113 (45)	117 (47)	123 (51)	128 (53)	134 (57)						
96 (36)	101 (38)	104 (40)	108 (42)	112 (44)	116 (47)	121 (49)	126 (52)	132 (56)					
94 (34)	97 (36)	100 (38)	103 (39)	106 (41)	110 (43)	114 (46)	119 (48)	124 (51)	129 (54)	135 (57)			
92 (33)	94 (34)	96 (36)	99 (37)	101 (38)	105 (41)	108 (42)	112 (44)	116 (47)	121 (49)	126 (52)	131 (55)		
90 (32)	91 (33)	93 (34)	95 (35)	97 (36)	100 (38)	103 (39)	106 (41)	109 (43)	113 (45)	117 (47)	122 (50)	127 (53)	132 (56)
88 (31)	88 (31)	89 (32)	91 (33)	93 (34)	95 (35)	98 (37)	100 (38)	103 (39)	106 (41)	110 (43)	113 (45)	117 (47)	121 (49)
86 (30)	85 (29)	87 (31)	88 (31)	89 (32)	91 (33)	93 (34)	95 (35)	97 (36)	100 (38)	102 (39)	105 (41)	108 (42)	112 (44)
84 (29)	83 (28)	84 (29)	85 (29)	86 (30)	88 (31)	89 (32)	90 (32)	92 (33)	94 (34)	96 (36)	98 (37)	100 (38)	103 (39)
82 (28)	81 (27)	82 (28)	83 (28)	84 (29)	84 (29)	85 (29)	86 (30)	88 (31)	89 (32)	90 (32)	91 (33)	93 (34)	95 (35)
80 (27)	80 (27)	80 (27)	81 (27)	81 (27)	82 (28)	82 (28)	83 (28)	84 (29)	84 (29)	85 (29)	86 (30)	86 (30)	87 (31)

	Heat Index	Possible heat disorders for people in high risk groups
Extreme Danger	130°F or higher (54°C or higher)	Heat stroke or sunstroke likely
Danger	105 - 129 °F (41 - 54°C)	Sunstroke, muscle cramps, and/or heat exhaustion likely. Heatstroke possible with prolonged exposure and/or physical activity.
Extreme Caution	90 - 105 °F (32 - 41 °C)	Sunstroke, muscle cramps, and/or heat exhaustion possible with prolonged exposure and/or physical activity.
Caution	80 - 90 °F (27 - 32 °C)	Fatigue possible with prolonged exposure and/or physical activity.

<u>What's the HI like in Georgia?</u>

During a typical afternoon in July or August, locations in northern and central Georgia have HI values in the *Extreme Caution* category, while locations in southern Georgia periodically have HI values in the *Danger* category.

<u>How can we minimize the effects of HI?</u>

As with the UVI, limiting exposure to the sun will reduce the effects of HI. For those who must be outdoors, the following precautions are advised:

- Take frequent breaks in the shade.
- Avoid prolonged exertion.
- Drink water often.

HOW WILL WE BE ADVISED OF WEATHER THAT WILL ADVERSELY AFFECT OUR VENUE/COMPETITION?

To fulfill its primary mission to protect life and property, the NWS uses *weather bulletins* to relay critical weather information to the public. For the 1996 Olympics, there will be three types of weather bulletins available in Info '96. Each bulletin type has a different purpose, therefore your response to a bulletin should be related to the type of bulletin that is issued. It is suggested that you prepare weather action plans in advance to define your venue's appropriate response to each bulletin.

The **WATCH** is one type of bulletin. When a watch is issued, it means that forecasters have determined (from observations and model predictions) that *conditions are favorable for significant weather*, say lightning, in and near an area.

Although significant weather may be far from occurring, the purpose of a watch is to raise your level of awareness and allow you ample time to prepare for the possible issuance of warnings. The types of watches that will be issued for the Olympics support are:

- Severe Thunderstorm Watch - conditions are favorable for thunderstorms with winds equal to or greater than 58 mi/hr (93 km/hr) and/or hail equal to or greater than ¾" (1.9 cm) in diameter.

- Tornado Watch - conditions are favorable for tornadoes to develop from severe thunderstorms.

- Flash Flood Watch - conditions are such that there is a threat of flooding due to heavy rainfall in a short period of time, usually less than 6 hours.

- Heat Watch - conditions are favorable for the Heat Index to reach 100° F (38° C) or more. This is the level at which heat stroke may become possible (see chart above).

- Lightning Watch - conditions are favorable for lightning to occur in the specified time.

- Separate watches will be issued for hail smaller than ¾" (1.9 cm), rain, wind speed and direction, visibility and other phenomena based on criteria you and your colleagues have established for your respective venues (see chart below).

Venue	Sport/Event	Hail	Rain	Wind Spd	Wind Dir	Vis	Other
Accreditation Center	Non-competition site	>3/4" (svr)	Heavy	>30 mph			
Airport Welcome Ctr	Non-competition site	>3/4" (svr)	Heavy	>30 mph			
Alexander Mem. Col.	Boxing	Any	Heavy	>30 mph			
Aquatic Center (GT)	Diving	Any	Heavy	>20 mph			
Aquatic Center (GT)	Swimming/Polo	Any	Heavy	>55 (svr)			
Atlanta-Fulton Co. Stad.	Baseball	Any	Any	>55 (svr)		<1 mi	
Centennial Oly. Pk.	Non-competition site	Any	Heavy	>30 mph			
Clark-Atlanta Univ.	Hockey	>3/4" (svr)	Heavy	>30 mph		<1 mi	
Georgia Dome	Gymnastics/Basketball	Any	Heavy	>30 mph			
Georgia State	Badminton	Any	Heavy	>30 mph			
Georgia WCC	Various	Any	Heavy	>30 mph			
Int'l Broadcast Center	Non-competition site	>3/4" (svr)	Heavy	>30 mph			
Main Press Center	Non-competition site	>3/4" (svr)	Heavy	>30 mph			
Marathon/Race Walk	Marathon/Race Walk	>3/4" (svr)		>55 (svr)			
Morehouse College	Basketball	Any	Heavy	>30 mph			
Morris Brown College	Hockey	>3/4" (svr)	Heavy	>30 mph		<1 mi	
Olympic Family Hotel	Non-competition site	>3/4" (svr)	Heavy	>30 mph			
Olympic Stadium	Open/Close Crmny	>3/4" (svr)	Heavy	>30 mph			
Olympic Stadium	Track and Field	Any	Heavy	>30 mph	> 90 deg		
Olympic Village	Non-competition site	Any	Heavy	>30 mph			
Omni	Volleyball	Any	Heavy	>30 mph			
Road Cycling Course	Road Cycling	Any	Heavy	>30 mph	> 90 deg	<1 mi	
Stone Mtn Archery	Archery	Any	Any	>30 mph			
Stone Mtn Tennis Ctr	Tennis	Any	Any	>30 mph			
Stone Mtn Velodrome	Cycling	Any	Any	>20 mph	> 90 deg		T - Td < 5
GIHP	Equestrian/Mtn Biking	Any	Heavy	>30 mph		<1 mi	
Wolf Creek	Shooting	Any	Heavy	>30 mph	> 90 deg	<1 mi	
Atlanta Beach	Beach Volleyball	Any	Any	>30 mph			
Lake Lanier	Rowing	Any	Heavy	>10 mph	> 90 deg		
Golden Park	Softball	Any	Heavy	>30 mph		<1 mi	
Sanford Stadium	Football	Any	Any	>30 mph			
UGA Coliseum	Gymnastics/Volleyball	Any	Heavy	>30 mph			
Ocoee River	White Water Kayaking	>3/4" (svr)	Heavy	>30 mph			

"Heavy Rain" in this table means watches and/or warnings will be issued for rain falling at a rate of 0.3 inches (8 mm) or more per hour. In layperson's terms, this is a standard "downpour."

The **WARNING** is the second type of bulletin. A warning means that a *significant weather phenomenon is occurring, is about to occur, or is suspected* based on reliable sources. Warnings will be issued with as much lead time as possible whenever any significant weather meets established criteria. When a warning is issued, take appropriate actions immediately! The types of warnings to be issued during the Olympics match one-for-one the watch types listed above.

The **WEATHER STATEMENT** is the third type of bulletin. It will be issued to advise you of changes in the weather that require watching. In particular, these statements will be issued frequently after the issuance of each warning and will be available on Info '96.

What should I do about lighting warnings?

First and foremost, you should have pre-designated "lightning-safe" areas. These areas can be tents or other temporary shelters as long as they are grounded well, with lighting rods at their highest points and attached cables running along the roof line to a deeply-buried grounding rod in a non-traffic area. Lightning rods do not necessarily "attract" lightning, but if an electric charge were to build in the vicinity, a lighting rod would either dissipate the charge slowly (thereby preventing a lightning strike) or channel the lightning bolt to the ground via a harmless route. By placing lightning rods and their associated cabling over and around a shelter, you essentially build a "lightning-deflecting cage" around the occupants of the shelter. You will need to ensure that people stay away from the grounding cables, though.

As mentioned above, a lightning warning will be issued for a venue if lightning is imminent or occurring in the area. In this case, you should take immediate action to make your area as "lightning safe" as possible. Moving people into lightning-safe shelters such as those described above would be best. Buses, cars and other covered vehicles also serve as excellent lightning-safe areas because they deflect lighting around the occupants of the vehicle.

If shelter is not available, the best thing to do is make people as "short" as possible, avoiding other tall objects. Lightning is a big killer of those who are standing out in the open or next to trees and other tall objects.

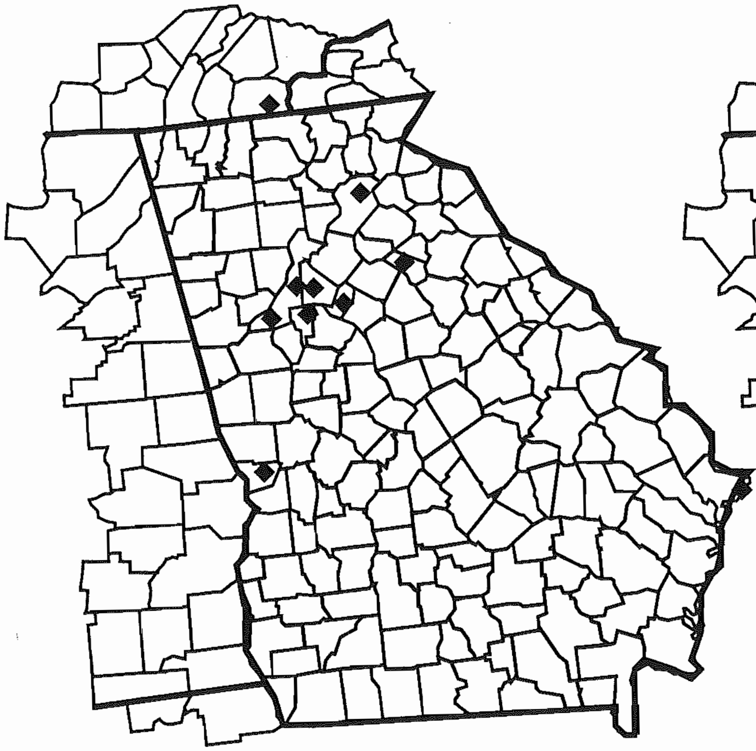
Appendix B

OWSO Mesoscale Form

Date _____________ Mesoanalyst Initials ________

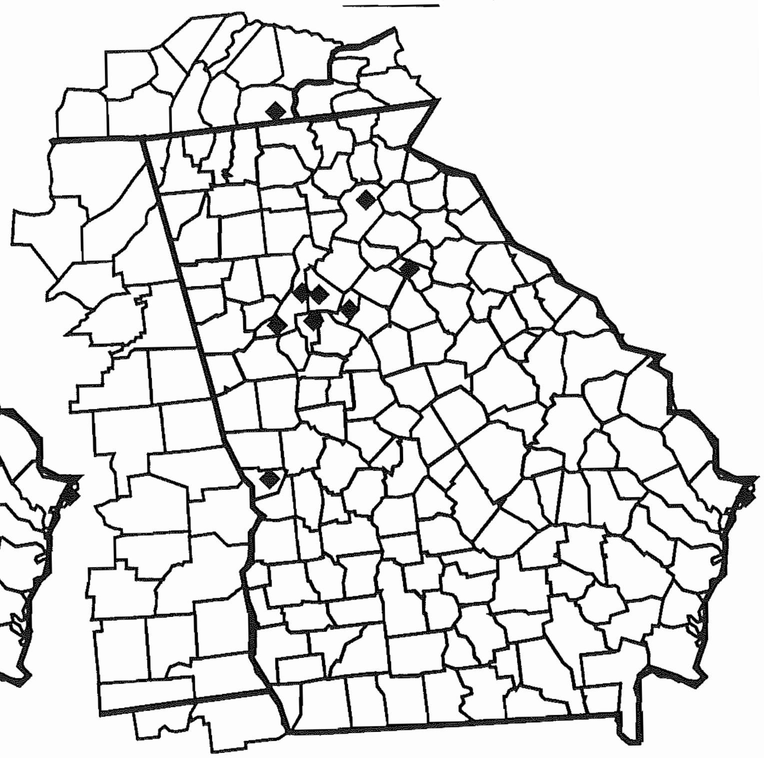
Time _____:40 LDT

Key Mesoscale Features

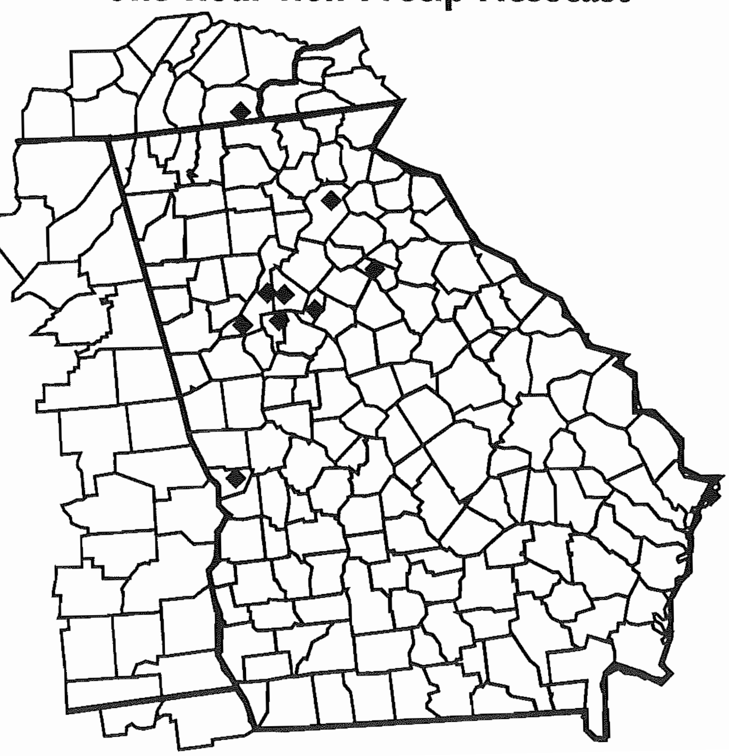


First Echo & One-hour Precip Mesocast

Valid _______:00 LDT



One-Hour Non-Precip Mesocast



Instructions

Key Mesoscale Features

1. Contour existing 20 DBz echoes.
2. Draw, in dashed lines, any discernable boundary (thermal, cloud, wind shift, fog shadow, etc.). Retain a boundary from previous analyses if any evidence supports its existence.
3. Contour and cross-hatch any area precip fell in the past 24 hours.

First Echo & One-Hour Precip Mesocast

1. Shade in a four-county block in which echoes ³20 dBz are forecast to form. Indicate initiation time next to block.
2. Contour forecast locations of echoes ³20 dBz (solid lines) and lightning (dashed).

One-Hour Non-Precip Mesocast

1. Forecast 10, 20 and 30 mph isotachs (solid lines).
2. Forecast >90 deg. wind shift lines (dashed lines).
3. Forecast location of RH >90% (scalloped lines) and shade forecast areas of fog and/or condensation.

Appendix C
Organizations Assisting in NWS Olympics Weather Support

Atlanta Committee for the Olympic Games
Atmospheric Environment Service, Canada
Auburn University
Bureau of Meteorology, Australia
Campbell Scientific, Incorporated
Center for Analysis and Prediction of Storms
Colorado State University
Coop. Program for Operational Meteor., Education & Training
Cooperative Institute for Research in the Atmosphere
Cray Research, Incorporated
Environmental Technical Laboratory, OAR
Florida State University
Forecast Systems Laboratory, OAR
Georgia Environmental Protection Department
Georgia Forestry Commission
Georgia Tech Research Institute
Georgia Technical University
International Business Machines, Incorporated
John Chandioux Consultants, Inc
METEO France
Mountain Administrative Support Center, NOAA
National Center for Atmospheric Research
National Centers for Environmental Prediction
- Central Operations
- Environmental Modeling Center
- Hydrometeorological Prediction Center
- Climate Prediction Center
- Storm Prediction Center
- Aviation Weather Center
- Tropical Prediction Center

National Climatic Data Center, NESDIS
National Data Buoy Center
National Ocean Service
National Severe Storms Laboratory, OAR
NEC, Inc.
NWS Regional and National Headquarters
NWSFOs Peachtree City, Birmingham, Miami, Sterling,
NWSOs Melbourne, Nashville, Charleston, Tallahassee, Jacksonville
NOAA Corps
Office of Public Affairs, NOAA
Office of Research and Applications, NESDIS
Oklahoma Climate Survey
Skidaway Institute of Oceanography
South Carolina Forestry Commission
Southeast Regional Climate Center
Southeast River Forecast Center
Techniques Development Laboratory, NWSH
Texas A&M University
Unisys, Inc.
University of Georgia
USAF Environmental Technical Applications Center
U.S. Coast Guard
World Meteorological Organization

Appendix D

Those Who Made the Olympic Weather Support Happen...

Abeles, James
Abeling, William
Ableman, Cyndie
Adams, Mark
Ahlert, Sally
Ahman, John
Albers, Steve
Albertelly, Mark
Albright, Wayne
Alex, Christine
Alexander, Lyle
Alford, Van
Alpert, Jordan
Alvarez, Kira
Anglin, Buck
Anthony, Richard
Anuini, Tony
Arguelles, Lori
Artusa, Anthony
Auciello, Gene
Austin, Glenn
Babin, Gille
Baer, Don
Bailey, George
Baker, Dr. James
Baldwin, Mike
Bales, Betty
Balfour, Rob
Ballegas, Rafael
Bandy, Rich
Banks, Kim
Barker, Llyle
Barnes, Wally
Barnston, Tony
Barr, David
Beckwith, Susan
Beehler, Sheila
Beeley, Gary
Belville, Jim
Benner, Mark
Bermawitz, Bob
Berry, John
Bin, Luo
Binns, Lindy
Birdow, Gerald
Birkenheuer, Dan
Blair, Jim
Blaskovich, David
Bothwell, Phil
Boucher, Nancy
Bradbury, Judy
Brenner, Ira
Brewster, Keith
Bright, David
Brill, Keith
Brodnax, Barry
Brooks, Harold
Brown, Maxine
Brown, Milton
Brown, Paige
Brown, Ronald
Bruce, Ann
Bryant, Andy
Bucklin, Leonard
Bullock, Carl
Burek, Buzz
Burgess, Brian
Burr, Christopher
Bushong, Jack
Butler, Gary
Byrd, Pat
Calos, Angela
Cano, Louis
Capus, Steve
Carle, Bob
Carle, William
Carr, Ray
Caulkins, Jim
Chandioux, John
Chang, Michael
Chao, Yung
Chartuk, Bob
Christidis, Zaphiris
Churchill, Brad
Cisco, James
Clark, Delores
Clarke, Brian
Cobb, Hugh
Coleman, Jason
Comba, Chris
Como, Art
Considine, Tanya
Conway, Bill
Cook, Laura
Cooper, Steven
Corfidi, Steven
Courton, Steve
Cowie, Jim
Crawford, Ken
Cray Research, Inc.
Cress, Sandra
Cromwell, Craig
Crosby, Don
Crothers, Carol
Crown, Helen
Curnutt, Jerry
Curran, John
Cutler, Nancy
Dahlgren, Don
Daniels, Ken
Darling, Alan
Daudelin, Gaétan
Davidowicz, Diane
Daynard, Josh
DeBerry, Ed
Decker, Dennis
Delaney, Gerry
Derham, Jack
Derouin, Bob
DesJardin, Mary

Dicarlo, Vince
Diehl, Philip
DiMego, Geoff
Dixon, Rich
Dombrowski, Rainer
Ducharme, Pierre
Duggan, Christine
Duke, C. Nolan
Dumeyer, John
Duval, Paul
Dye, Anita
Dyer, Camille
Earhart, Mike
Eckert, Michael
Eddy, Steve
Edmonston, Mike
Edwards, Jim
Eilts, Mike
Eimiller, Ron
Elson, Dave
Embleton, Robert
Exler, Randee
Faciane, Dave
Fahey, Patrick
Fair, Cynthia
Farley, Micki
Fatovic, Bob
Faught, Diane
Faust, Nick
Fauver, Stephanie
Fenix, Jim
Flatt, Paul
Flood, Steve
Formhals, Tom
Forsyth, Doug
Foster, Charles
Frantz, Kent
Friday, Dr. Joe
Fritz, Pedro
Gajdys, Lois
Garcia, Martin
Garrison, William
Gartner, Bill
Garza, Carlos
Garza, Reggina
Gaudette, Mario
Getz, Rodger
Gibbs, Bob
Gibson, Chris
Gingrich, Tim
Gird, Ron
Glahn, Bob
Glickman, Todd
Glover, Eric
Gooden, Barry
Gooden, Glenda
Goodman, Bill
Goree, Bob
Gorre-Dale, Eirah
Gosden, Hiro
Gregory, Terry
Gresham, Dee Dee
Grice, Gary
Grimaila, Annette
Groover, Charles
Gross, Ed
Grossman, Dave
Gudelis, Paul
Gudgel, Dan
Haga, Bill
Hagemeyer, Bart
Haines, Steven
Hales, Jack
Hall, Clarence
Hamilton, Todd
Hanson, Greg
Hart, Patricia
Hassel, Harry
Hebert, Paul
Hedge, Chris
Heil, James
Helms, Dave
Henderson, Jim
Henderson, Suzanne
Hendrickson, John
Hess, Doug
Hewlett-Packard Corp.
Highberger, Ken
Hill, Doug
Hill, Lloyd
Himes, David
Holle, Ron
Holmes, J.D.
Hondl, Kurt
Hoogenboom, Gerritt
Hoopingarner, John
Hoppa, Jennifer
Horel, John
Houston, Julie
Hoxsie, Kathy
Hughes, John
Humphreys, Johnny
Hutsell, Dean
IBM
Iffland, Fred
Irvin, Lloyd
Jacobs, Mary
Jacobs, Scott
Jacobson, Chris
Jain, Mike
Janish, Paul
Jenkins, Kirsten
Jesuroga, Susan
Johns, Bob
Johnson, Bryant
Johnson, JT
Johnson, Lori
Jones, Brad
Juang, Henry
Junker, Wes
Keiser, Dave
Kelleher, Kevin
Keller, Dave
Kelly, Gerry
Kelly, Harold
Kenitzer, Stephanie
Keppler, Barb
Kercher, Barry
Keyser, Dennis
Kitt, Jennifer
Klein, Mark
Kling, Erika
Kneas, Bill
Korty, Brian
Kouhestani, Jeanne

Krein, Andrew
Kreiss, Bill
Krueger, Leroy
Lachapelle, Andre
Laing, John
Lakshmanan, V.
Lamback, Shirley
Landis, Bob
Lang, Joe
Lange, Rhonda
Langley, Jeff
LaPore, Frank
Lashley, Sam
Laver, Jim
Lavin, Kevin
Layman, Jim
Leary, Mike
Lebowitz, Steven
Lee, James
Lee, Tiros
Lefebvre, Robert
Lessard, Arthur
Lewis, Pam
Li, Lin
Lin, Chien
Linda, Mike
Linda, Mike
Lindner, Art
Lish, Jim
Livezey, Bob
Livingston, Eric
Lloyd, Harold
Logan, Dan'Yale
Luca, Rob
Lundchild, Nick
Lynn, Brian
Lynn, Jason
Lynn, Kelly
MacGorman, Don
MacIntosh, John
MacKeen, Pam
Maddox, Bob
Madigan, Martha
Maguire, Bonnie
Mall, Scott
Mandeville, Roland
Marks, Bill
Marshak, Bruce
Martin, Elizabeth
Martin, Rusty
Martin, Shawn
Marzban, Karen
Masuka, Muata
Matzen, Greg
Mausser, Paul
Mayes, Nate
Mazur, Vlad
McBean, Gordon
McCall, Jerry
McClung, Tim
McCollum, Darren
McDonald, Sandy
McGinley, John
McGowen, James
McKay, John
McKibben, Loretta
McLaughlin, Mac
McMullen, Kent
McPherson, Karen
McPherson, Ron
McQueen, Jeff
Meiggs, Ronla
Melcher, Donna
Mentzer, Scott
Michaud, Robert
Miller, Fred
Miller, Ron
Mitchell, DeWayne
Mogil, Mike
Molenar, Deb
Mollere, Greg
Moore, Patrick
Morisette, Jean
Morone, Lauren
Morre, John
Mosher, Fred
Mostek, Tony
Moxam, Andrew
Murphy, George
Murphy, M. Patrick
Murphy, Ron
Murphy, Terry
Murrell, Verona
Mycoskie, Cyndy
Nealson, Dennis
Neault, Gerard
Nelson, Cynthia
Nelson, Steve
NHC Aviation Wx Ctr
Nichols, Suzanne
Niziol, Tom
NLSC
Noar, Peter
Noffsinger, Jim
Nolt, Jim
NRC
NWSFO Birmingham
NWSFO Miami
NWSFO Norman
NWSFO Peachtree City
NWSFO Portland
NWSFO Sterling
NWSO Charleston
NWSO Goodland
NWSO GSP
NWSO Jacksonville
NWSO Melbourne
NWSO Nashville
O'Lenic, Ed
O'Neal, Brenda
Oberfield, Mark
Olsen, Laurie
Olson, David
Oravec, Bob
Orville, Richard
OSF Training Branch
Ostby, Fred
Outlaw, Doug
Padgett, Shirley
Pappas, Roger
Parkerson, Don
Parrish, David
Parrish, Steve
Patstone, Todd
Pearson, Col. Doug

Pena, Robert
Pence, Kevin
Peroutka, Matthew
Perrota, Sue
Peters, Brian
Peters, Chris
Peters, Joyce
Petti, Gary
Phillips, Felicia
Pincu, Jenny
Pinkerton, Mike
Pinkerton, Mrs.
Plummer, Dave
Poteat, Hope
Powell, Kenneth
Powell, Mark
Prajsner, Terry
Przywarty, Rich
Purdom, Jim
Quick, Judy
Quinglu, Lin
Rattray, Ronda
Rausch, Marty
Reed, Larry
Reese, Courtney
Reichenbaugh, Barry
Rhue, Doug
Rich, Steve
Rickett, Crystal
Rinard, Steve
Riordan, Alan
Rippen, George
Ripps, Alma
Robson, Alan
Rodenhuis, David
Rodriguez, Jose
Rodriguez, Ric
Roebel, Jeff
Rogash, Joseph
Rogers, Eric
Rolen, Jeanette
Rosemark, Mike
Rosenstein, Frank
Ross, Mike
Ross, Tom
Rothfusz, Kathy
Rothfusz, Lans
Rowe, Steve
Roy, Sarah
Russ, Ashley
Ruth, Dave
Ryan, Chris
Rydell, Nezette
Sabones, Mike
Safford, Clark
Sakata, Dan
Sammler, William
Sanger, Sarah
Scally, Doug
Scasny, Kimberley
Schaeffer, Mark
Schaub, Bill
Schichtel, Mike
Schmidt, Craig
Schnieder, Russ
Schoenberger, Cliff
Schotz, Steve
Schriner, Peggy
Scott, Steve
Seaborn, Marty
Sena, Matt
Sévigny, André
Seymour, Eric
Sharp, Dave
Shepard, Dave
Sherman, Lance
Sherrieb, Dave
Shirey, Mark
Shogren, Marvin
Siebers, Tony
Silva, Don
Skagg, Mike
Skaggs, Gary
Skowronek, Joe
Slaff, Jerry
Slattery, Pat
Smart, John
Smart, John
Smith, Brenda
Smith, Chris
Smith, Dan
Smith, Matt
Smith, Roy
Smith, Travis
Snook, John
Snowny, Tom
Souther, Teresa
Spark, Elly
Spencer, Phillip
Spigelmire, Mike
Spratt, Scott
Stamus, Pete
Stern, Andy
Stevenson, Kathy
Steward, Jane
Stingley, Pat
Stumpf, Greg
Sullivan, Bruce
Swann, Brenda
Szatkowski, Gary
Tabul, Dave
Tamizawa, Paul
Taylor, Bill
Taylor, Frank
Taylor, Glenn
Taylor, Jason
Taylor, Joie
Terry, Bruce
Tevis, Cecil
Thomas, Jody
Thomas, Julia
Thomas, Kevin
Thomas, Linsey
Thurm, Harvey
Todd, Steve
Tollerud, Ed
Tomastik, Tim
Towle, Sheryl
Townsend, John
Trainor, Marilu
Travers, Jim
Treinish, Lloyd
Tucek, Dave
Tweed, Curt
Tyle, Kevin

Tylor, Wes
Uccellini, Louis
Ullom, Rick
Unger, Dave
Vaillancourt, Pierre
Valverde, Mario
Van den Dool, Hugh
Vandenberge, George
Vanderzon, Nicole
Vescio, Mike
Victory, John
Visbulis, Rick
Wagner, Robert
Wallenfang, Jeff
Ward, John
Watkins, Ben
Watson, Dave
Watson, Irv
Weaver, Susan
Wee, Michael
Weinbrenner, Dave
Weiss, Steven
Wharton, Linda
White, Max
Whitmore, Bill
Wiggins, Michael
Williams, Jack
Willis, Jerry
Wilson, Bill
Witsman, Gene
Witt, Arthur
Witte, Joe
Wobus, Richard
Wohl, Gary
Wolf, Eric
Woods, Von
Wright, Dean
Wrigley, Richard
Wu, Peter
Yanover, Jonathon
Yarborough, Mark
Yerg, Martin
Young, Sondra
Younger, Michelle
Yuwono, Leo
Zaleski, Walt
Zaras, Daphne
Ziegenfelder, Paul
Zika, Matt
Zillman, John
Zimmerman, Eric

And all the family members who supported from home during the long absences & long workdays!!